NORTHERN GREAT PLAINS
RESOURCES PROGRAM

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USDA FOREST SERVICE

REHABILITATION POTENTIALS AND LIMITATIONS OF SURFACE-MINED LAND IN THE NORTHERN GREAT PLAINS

Paul E. Packer

USDA Forest Service
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Intermountain Forest and Range
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The Northern Great Plains Resources Program, an interagency, multi-State effort under leadership of the U.S. Department of the Interior, has the primary objective of providing an analytical and informational framework for policy and planning decisions at all levels of Government. The resource information provided by the Program is intended to be a decision-making tool for Federal, State, and local interests who together must plan and manage the Great Plains area's land and natural resources.

SEAM, an acronym for Surface Environment and Mining, is a Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping meet the Nation's mineral requirements. SEAM is a partnership with all land managers, regional planners, mining industries, and political jurisdictions at all levels.

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ABSTRACT

Man disturbs his environment by digging into the earth to obtain minerals that satisfy his needs. Society benefits in many ways, but in the process large areas may be defiled and waters polluted. In the case of surface mining for coal in the Northern Great Plains, reclamation may be possible.

The Northern Great Plains coal province occupies approximately 141,448 square miles. Of this, about 4,062 square miles (2.8 percent) of the area, are underlain by surface mineable coal deposits.

An emerging environmental quality problem in the Northern Great Plains is rehabilitation of the spoils left in the wake of mining these coal deposits. Needed are criteria and guides for predicting rehabilitation potentials and limitations on various kinds of surface-mined lands. Equally important is the need to define and prescribe rehabilitation treatments for different kinds of land, and posttreatment management measures.

Important factors influencing the potentials of different kinds of land for growing vegetation and also their rehabilitation with vegetation are (1) amount and distribution of precipitation, (2) soil productivity and stability, and (3) suitability and availability of plant materials for rehabilitation purposes. These factors provide the basis for classifying surface mineable lands in the Northern Great Plains into areas that can reasonably be assumed to have different potentials for supporting seeded and planted vegetation. These areas of land have been named rehabilitation-response units.

Approximately 86 different kinds of rehabilitation-response units involving 146 different areas of land comprise the surface mineable lands of the Northern Great Plains. Sixteen coal surface mines and three bentonite surface mines, located on 14 kinds of

rehabilitation-response units, have a history of rehabilitation research or of action programs. These histories provide some short-term evaluations of success for comparison with predicted potentials.

Results of actual rehabilitation efforts indicate the need for certain constraints concerning disposition of toxic spoils, steepness of slopes, mulching, use of fertilizers, application of soil amendments, and irrigation. If such constraints are recognized and observed, the potential for successful rehabilitation of surface-mined lands in the Northern Great Plains ranges from fair to excellent. Sites that have the highest rehabilitation potentials occur in rehabilitation-response units characterized by productive and stable soils, suitable and available plant species, and adequate amounts of precipitation. In general, these high potential sites are in west-central North Dakota. Surface mineable sites that have intermediate rehabilitation potentials occur predominantly in southeastern Montana and extreme western North Dakota. Sites that have the poorest potentials for rehabilitation occur in northeastern Wyoming and northeastern Montana, where rehabilitation-response units are characterized by poorly productive soils, low amounts of precipitation, and native species that grow slowly and are difficult to obtain for rehabilitation purposes.

Fortunately, those portions of the Northern Great Plains that present the most difficult rehabilitation problems are also the smallest areas to be disturbed for a given amount of extracted coal. Conversely, the easiest rehabilitation problems exist in those portions of the Northern Great Plains where the greatest areas of disturbance take place per unit of extracted coal.

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CONTENTS

INTRODUCTION

Adverse effects on the environment caused by surface coal mining are major national concerns. Americans are aware that the quality of life is directly related to the quality of the environment. Ever-increasing demands for coal, a primary energy source, coupled with technological advancement in extraction techniques, have increased surface mining of coal. Mining and processing coal for energy utilization have often resulted in what is now perceived to be unacceptable degradation of the environment. Effects on the environment have varied, mainly in degree rather than in kind. Surface coal mining has not been a major contributor to air pollution. However, processing coal by combustion to produce energy has resulted in stack emissions and in major air pollution. Consequences of surface mining have been most noticeable on the land. Vegetation has been destroyed, soils turned upside down, and large areas left as bare, unsightly spoil banks. Natural beauty and topography have been greatly altered. Some areas have lost their productivity; only a small percentage of strip-mined lands has been restored. Surface mining for coal has polluted surface and ground water resources in those parts of the country where the coal has a high sulfur content. Fortunately, surface mining for coal in the Northern Great Plains is expected to have less serious effect on water resources than those encountered elsewhere, especially in the eastern coalfields.

Various actions can mitigate undesirable effects of surface mining in the Northern Great Plains. Such actions include: (1) planning when, where, and how much coal or other mineral resources are to be mined consistent with the management of other resources and also with community, regional, and national social and economic needs; (2) incorporation of environmental protection requirements in prospecting and mining leases; (3) employment of appropriate mining techniques; (4) adequate supervision of mining operations; and (5) rehabilitation of disturbed areas.

Rehabilitating surface-mined lands involves shaping spoil piles to desirable configurations, application of available surface soil, and planting of suitable vegetation. Major factors influencing success of a surface-mine rehabilitation program are the chemical, hydrologic, and physical characteristics of reshaped spoil materials as they influence productivity; the climatic characteristics of the site reflected by amounts and distribution of precipitation and the potential for evapotranspiration; and the availability of seeds and propagated plant parts of both native and suitable introduced plant species. Current rehabilitation concepts entail returning sites as nearly as possible to their original condition. Hills and valleys are created to simulate natural variety in the landscape. On drier sites, irrigation can facilitate better or more rapid response of seeded or planted vegetation. Land disturbance

involved in rehabilitation treatments often creates conditions conducive to wind and water erosion (e.g., soil may be compacted by some of the operations and sediment levels in streams may be temporarily increased). However, environmental damage resulting from rehabilitation treatments is generally ephemeral and necessary if sites are to be brought to their former or higher productive capacities, to their original or improved vegetation covers, and to their former or more suitable land uses.

The objectives of this report are as follows:

1. To summarize pertinent information relative to important factors that affect rehabilitation potentials on surface-mined lands on the Northern Great Plains. Factors that influence rehabilitation potentials include climate, geology, physiography, soils, availability of adaptable vegetation, mining techniques, and post-mining methods for handling spoils. However, lack of detailed information about these factors applicable on a site-specific basis precludes consideration of more than those few factors that bear most on surface mine-rehabilitation potentials;

2. To arrange those few factors into a system to delineate and classify surface mineable lands into units according to their rehabilitation-response potential;

3. To locate and classify each existing surface mine in the Northern Great Plains within its appropriate rehabilitation-response unit;

4. To describe the history of rehabilitation effort and success at each mine for which information was available in the summer of 1973;

5. To determine the areas of different rehabilitation-response units by States and counties for the three alternative coal resource development forecasts and time periods assumed for the Northern Great Plains;

6. To develop rating criteria and to rate rehabilitation potentials of the particular kinds of response units found in the Northern Great Plains;

7. To weight each rehabilitation-potential rating by the appropriate area of the response unit to which it applies. This method provides a comparative rating of rehabilitation potentials among response units;

8. To compare these rehabilitation-potential ratings with the actual degree of rehabilitation success experienced on individual mines. This comparison will indicate the adequacy of the rating criteria for estimating the rehabilitation potentials of response units;

9. To indicate the nature of problems and the kinds of research relating to rehabilitation potentials that need attention in the Northern Great Plains.

These objectives comprise the sequence of data acquisition, classification, analyses, and interpretation that should result in predictions of potentials for rehabilitating different kinds of land in the Northern Great Plains that might eventually be surface mined. Because of the lack of detailed information concerning results of rehabilitation efforts on the relatively new mines in the Northern Great Plains, it is not expected that the predictive capability emanating from this study will be useful on a site-specific basis. The results of this study will be useful for predicting potential rehabilitation success on larger tracts of land characterized by soil associations, broad vegetative types, and average annual precipitation characteristics. Site-specific information regarding these influencing factors is required to produce site-specific rehabilitation prescriptions.

STUDY AREA

The Northern Great Plains are expansive prairie lands bounded on the west by the Rocky Mountains in Montana and Wyoming. They contain the Northern Great Plains coal province, which occupies approximately the eastern third of Montana, the western half of North Dakota, the northeast quarter of Wyoming, and the northwest tenth of South Dakota. Most of the nation's Federal coal lies in this province.

The largest region in the Northern Great Plains coal province is the Fort Union region which encompasses the western half of North Dakota and parts of South Dakota and Montana. This region contains an estimated 440 billion tons of lignite, by far the largest coal resource in the entire United States (Landis 1973). Most coal is in the Ludlow, Tongue River, and Sentinel Butte members of the Fort Union formation. Coalbeds are discontinuous and vary greatly in thickness. More than a hundred coalbeds have been identified, but no more than three beds of commercial thickness have been found in any one section. Coal throughout most of the Fort Union region is lignite.

The Powder River region, southern extension of the Fort Union region, continues from southern Montana into northeastern Wyoming. This region contains nearly 240 billion tons of sub-bituminous coal (Glass 1972).

The geologic formation containing these coal deposits consists of from 1,700 to 3,200 feet of sandstone, shale, and coal. In general, coalbeds are thickest in Wyoming. Some important coalbeds are the Badger and School seams at Glenrock, the Monarch seam near Sheridan, the Healey bed near Lake Desmet, and the famous Wyodak bed near Gillette.

Bentonite clay beds occur in southeastern Montana, northeastern Wyoming, and the western Dakotas. Bentonite beds are most extensive and bentonite mining more active near the three-State junction of South Dakota, Wyoming, and Montana.

REGIONAL CHARACTERISTICS OF IMPORTANT FACTORS AFFECTING REHABILITATION POTENTIALS

The important factors that determine probabilities for successfully rehabilitating surface-mined lands in the Northern Great Plains are (1) the amount and distribution of precipitation, (2) the productivity and stability of soils, and (3) the suitability and availability of different plant species for revegetation purposes.

Precipitation Amounts and Distribution

According to Thornthwaite (1931), Northern Great Plains climate is generally of the semiarid type. One example of 37 years of observations shows semiarid conditions during 25 years, dry subhumid or arid, 5 years each, humid or moist subhumid, 1 year each, and no years of superhumid conditions, based upon the precipitation-evaporation index (Thornthwaite 1941). Thornthwaite (1941) wrote: "In a desert, you know what to expect of the climate and plan accordingly. The same is true of the humid regions. Men have been badly fooled by the semiarid regions because they are sometimes humid, sometimes desert, and sometimes a cross between the two. Yet, it is possible to make allowances for this too, once the climate is understood." The climate of a region cannot be fully described by a single element such as precipitation or temperature. Climate is comprised of numerous elements such as precipitation, air temperature, soil temperature, humidity, wind velocity, atmospheric pressure, solar terrestrial radiation, and snow cover. Generally, however, only one or two climatic elements preponderantly influence the nature of the climate in any particular region. In the semiarid Northern Great Plains, the most important climatic element that determines relative agricultural success is the amount of seasonal precipitation, coupled with its distribution pattern (Thornthwaite 1931). The frequency of occurrence of different climatic types varies greatly in this area.

In some years, the amount and seasonal distribution of rainfall in the Northern Great Plains is entirely adequate for successful agriculture; in others, the rainfall is so reduced that successful crop production is unlikely. No corresponding risk exists in a continuously arid climate because the weather never encourages agricultural attempts. In the Northern Great Plains, precipitation surpasses that of the semiarid climates with sufficient frequency to encourage agricultural endeavors, but not to assure successful agriculture every year.

Table 1.--*Areas of various precipitation zones on surface-mineable lands by States and counties in the Northern Great Plains*

State and County	Precipitation zones — Inches						
	<12	12	13	14	15	16	>16
	Acres						
Wyoming							
Campbell	35,386	76,358	32,282	22,349	29,798	89,395	
Converse	0	17,382	19,866	7,450	0	0	0
Johnson	0	0	0	0	39,731	0	0
Sheridan	0	0	0	0	37,248	0	0
Weston	0	0	0	0	0	0	14,899
Total	35,386	93,740	52,148	29,799	106,777	89,395	14,899
Montana							
Bighorn	0	0	0	39,731	166,374	2,483	0
Custer	0	0	32,282	17,382	39,731	0	0
Dawson	0	12,416	12,416	0	0	0	0
Fallon	0	0	34,765	0	0	0	0
Garfield	0	278,118	0	0	0	0	0
McCone	0	99,328	0	0	0	0	0
Musselshell	0	7,450	2,483	0	0	0	0
Powder River	0	0	0	0	139,059	81,946	22,349
Richland	0	64,563	17,382	7,450	0	0	0
Roosevelt	0	0	17,382	0	0	0	0
Rosebud	0	0	0	7,450	19,866	94,362	22,349
Sheridan	0	0	32,282	0	0	0	0
Treasure	0	0	24,832	4,966	0	0	0
Wilbaux	0	0	0	44,698	0	0	0
Total	0	461,875	173,824	121,677	365,030	178,791	44,698
North Dakota							
Adams	0	0	0	0	0	49,664	0
Billings	0	0	0	0	22,349	0	0
Bowman	0	0	0	0	22,349	0	0
Burke	0	0	0	0	22,349	0	0
Burleigh	0	0	0	0	0	7,450	
Dunn	0	0	0	0	22,349	0	0
Golden Valley	0	0	0	37,248	0	0	0
Hettinger	0	0	0	0	0	109,261	0
McLean	0	0	0	0	9,933	9,933	0
Mercer-Oliver	0	0	0	0	47,181	91,878	0
Slope	0	0	0	24,832	52,147	37,248	0
Stark	0	0	0	0	62,080	34,765	0
Ward	0	0	0	0	7,450	9,933	0
Williams	0	0	0	12,416	9,933	0	0
Total	0	0	0	74,496	278,120	350,132	0
South Dakota							
Butte	0	0	0	52,147	0	0	0
Meade	0	0	0	0	76,979	0	0
Total	0	0	0	52,147	76,979	0	0
TOTALS	35,386	555,615	225,972	278,119	826,906	618,318	59,597

Average annual precipitation in the Northern Great Plains ranges from 8 to 24 inches; the largest portion of the area receives between 10 and 16 inches. More than 90 percent of the surface mineable lands in the Northern Great Plains receive between 12 and 16 inches. The greatest amount of precipitation occurs along the eastern boundary of the region in western North Dakota and in the Black Hills of South Dakota; the least amount falls in northeastern Wyoming and northeastern Montana. Precipitation throughout the region is heaviest from April to September, when up to 75 percent of the annual amount is recorded. Summer rains, usually from the Gulf of Mexico, are mostly thunderstorms. The prevailing wind pattern is from the west or northwest. The western portion of the area is noted for its winds, which quickly dry out soils in summer and drift snow in winter. Normally the area receives less than 1 inch of precipitation per month in winter. The lines of equal precipitation (Isohyetal lines), although subject to some meandering, are north-south oriented; so precipitation generally increases about an inch for every 50 miles of movement eastward. During the growing season, distribution of precipitation is usually favorable for crop production. Rainfall is light in the spring, but increases from April until September, when it is needed most for vegetative growth. From September until December, declining precipitation and abundant sunshine favor maturing of both native and planted crops. A difference of only 1 or 2 inches of rainfall during the growing season can affect significantly the potential for rehabilitating surface-mined lands. Distribution of average annual precipitation in relation to surface mineable lands of the Northern Great Plains coal province is shown in figure 1 (map, back of book). Areas of the various precipitation zones occurring on surface mineable lands by States and counties are shown in table 1.

Soil Productivity and Stability[1]

Forty-two major soil associations are identified within the boundaries of the Northern Great Plains. These soil associations are depicted on Aandahl's (1972) map entitled "Soils of the Great Plains" and also are shown in figure 1. Of these 42 soil associations, only 17 occupy surface mineable areas; consequently, only these 17 soil associations are considered in this report.

Ten of these 17 soil associations are classified by Aandahl as typic (moderately moist) Borolls and Ustorthents. Borolls have horizons of accumulated clay that sometimes contain sodium. Ustorthents are sometimes dry, sometimes moist, receive summer rains, but lack moisture for plant growth for long periods. These 10 soil associations are mainly in western North Dakota, and are identified on Aandahl's soil map and in figure 1 by soil association numbers 19, 23, 25, 26, 27, 30, 31, 33, 34, and 35.

Soil association 44 is classified as Borollic (cold), Torriorthents (nearly always dry) Natrargids (much sodium on clays). This soil association occurs chiefly across the dry central-eastern plains of Montana and the extreme northwest corner of South Dakota.

Five soil associations, 109, 111, 117, 121, and 123, are classified as Ustic (alternately moist and dry), Aridisols (low in organic matter and usually dry), Camborthids-Haplargids (little or no soluble salts or sodium clays). These soil associations are found in southeastern Montana, northeastern Wyoming, and western North Dakota.

Soil association 184 is classified as a badlands Torriorthent (rocky and dry). This soil association is found only in a few places on the extreme fringe of surface mineable lands in the Badlands of the Little Missouri River in western North Dakota.

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[1] Based on removal and replacement of suitable soil strata as a spoil surfacing material.

These 17 soil associations are characterized with respect to their vegetative productivity and their stability as follows:

Soil Association 19.--A fine Argiboroll with a layer of clay accumulation in the C horizon; good productivity; occurs on level-to-undulating topography, slopes generally less than 8 percent; very good stability.

Soil Association 23.--A fine loamy Argiboroll on drier sites than soil association 19, good productivity; occures on level-to-undulating topography; good stability.

Soil Association 25.--A loamy Argiboroll; very good productivity (probably the most productive of the 17 soil associations); occurs on level-to-rolling topography, slopes up to 16 percent; good stability.

Soil Association 26.--A fine loamy Argiboroll; good productivity; occurs on level-to-rolling topography, slopes less than 16 percent; good stability.

Soil Association 27.--A clayey and fine loamy Argiboroll; fairly good productivity; level-to-rolling topography, slopes up to 16 percent; fairly stable.

Soil Association 30.--A loamy and sandy Haploboroll without any distinct accumulation of calcium carbonate, clay, or sodium; fairly good productivity; level-to-rolling topography, slopes up to 16 percent; fairly good stability.

Soil Association 31.--A fine loamy and loamy skeletal lithic Haploboroll; fair productivity; undulating-to-hilly topography, slopes up to 30 percent; poor stability.

Soil Association 33.--A fine silty and fine loamy Haploboroll; fair productivity; undulating-to-hilly topography; slopes up to 30 percent; poor stability.

Soil Association 34.--A fine loamy Ustorthent, with a heavy clay horizon; fair productivity; undulating-to-hilly topography, slopes up to 30 percent; poor stability.

Soil Association 35.--A shallow loamy Ustorthent, with a heavy clay horizon; fair productivity; undulating-to-steep topography, slopes in excess of 30 percent; very poor stability.

Soil Association 44.--A moderately deep loamy Borollic Torriorthent having a large amount of sodium on the clays; fairly poor productivity; undulating-to-hilly topography, slopes up to 30 percent; fairly poor stability.

Soil Association 109.--A clayey and loamy Ustic Aridisol, with a horizon of active or swelling clays; very poor productivity; undulating-to-rolling topography, slopes up to 16 percent; fair stability.

Soil Association 111.--A shallow clayey Ustic Aridisol, with a horizon of active or swelling clays; poor productivity; undulating-to-hilly topography, slopes up to 30 percent; fairly poor stability.

Soil Association 117.--A clayey and loamy Ustic Aridisol having a large amount of sodium on the clays; poor productivity; undulating-to-rolling topography, slopes up to 16 percent; fair stability.

Soil Association 121.--A shallow, loamy, and clayey Ustic Aridisol, dry much of the year; very poor productivity; rolling-to-steep topography, slopes in excess of 30 percent; very unstable.

Table 2.--*Areas of different soil associations occupying surface-mineable lands by States and counties in the Northern Great Plains*

State and County	Soil association																	
	19	21	23	24	25	26	27	30	31	33	35	44	109	111	117	121	123	184
	Acres																	
Wyoming																		
Campbell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	196,173	0	89,395	0
Converse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29,798	0	14,899	0
Johnson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17,382	0	22,349	0
Sheridan	0	0	0	0	27,315	0	0	0	0	0	0	0	0	0	0	0	9,933	0
Weston	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14,899	0	0
Total	0	0	0	0	27,315	0	0	0	0	0	0	0	0	0	243,353	14,899	136,576	0
Montana																		
Bighorn	0	0	0	0	29,798	0	0	0	19,866	0	0	0	0	0	104,294	0	54,630	0
Custer	0	0	0	0	0	0	0	0	54,630	0	0	17,382	0	0	0	0	17,382	0
Dawson	0	0	0	0	0	12,416	0	0	0	12,416	0	0	0	0	0	0	0	0
Fallon	0	0	0	0	0	0	0	0	0	0	0	34,765	0	0	0	0	0	0
Garfield	0	0	0	0	0	0	0	0	0	0	0	193,690	0	0	0	0	0	84,429
McCone	0	0	0	0	0	9,933	0	0	0	4,966	0	74,496	0	0	0	0	0	9,933
Musselshell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9,933	0
Powder River	0	0	0	0	0	0	0	0	193,690	0	0	0	0	0	14,899	0	34,765	0
Richland	0	0	0	0	0	52,147	0	0	0	29,798	7,450	0	0	0	0	0	0	0
Roosevelt	0	0	0	0	0	17,382	0	0	0	0	0	0	0	0	0	0	0	0
Rosebud	0	0	0	0	0	0	0	0	101,811	0	0	0	0	0	0	0	42,214	0
Sheridan	0	0	12,416	0	0	19,866	0	0	0	0	0	0	0	0	0	0	0	0
Treasure	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29,158	0
Wilbaux	0	0	0	0	0	0	29,798	0	0	7,450	7,450	0	0	0	0	0	0	0
Total	0	0	12,416	0	29,798	111,744	29,798	0	369,997	54,630	14,900	320,333	0	0	119,193	0	188,082	94,362
North Dakota																		
Adams	0	0	0	0	7,450	0	0	42,214	0	0	0	0	0	0	0	0	0	0
Billings	0	0	0	22,349	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bowman	0	0	0	4,966	17,382	0	0	0	0	0	0	0	0	0	0	0	0	0
Burke	22,349	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Burleigh	7,450	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dunn	0	0	0	4,966	0	0	0	17,382	0	0	0	0	0	0	0	0	0	0
Golden Valley	0	0	0	0	0	0	29,798	0	0	7,450	0	0	0	0	0	0	0	0
Hettinger	0	0	0	0	94,362	0	0	14,899	0	0	0	0	0	0	0	0	0	0
McLean	9,933	9,933	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercer-Oliver	34,765	7,450	24,832	0	12,416	0	0	0	0	0	59,596	0	0	0	0	0	0	0
Slope	0	0	0	34,764	47,181	0	0	0	0	0	29,798	0	0	0	0	0	0	2,483
Stark	0	0	0	49,664	14,899	0	0	12,416	0	0	19,866	0	0	0	0	0	0	0
Ward	17,382	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Williams	2,483	0	0	0	0	0	0	0	0	0	19,866	0	0	0	0	0	0	0
Total	94,362	17,383	24,832	116,689	193,690	0	29,798	86,911	0	7,450	129,126	0	0	0	0	0	0	2,483
South Dakota																		
Butte	0	0	0	0	0	0	0	0	0	0	0	37,248	0	14,899	0	0	0	0
Meade	0	0	0	0	0	0	0	0	0	0	0	0	76,979	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	37,248	76,979	14,899	0	0	0	0
TOTALS	94,362	17,383	37,248	116,689	250,803	111,744	59,596	86,911	369,997	62,080	144,026	357,581	76,979	14,899	362,546	14,899	324,658	96,845

Soil Association 123.--A shallow, loamy, and clayey Ustic Aridisol, dry much of the year, that has a large amount of sodium on the clays; poor productivity; undulating-to-hilly topography, slopes up to 30 percent; poor stability.

Soil Association 184.--A loamy and clayey Torriorthent, dry much of the year, very poor productivity; undulating-to-steep Badlands, slopes in excess of 30 percent; very poor stability.

Soil tests and field trials indicate that soils in Montana and Wyoming and west of the Missouri River in North Dakota are conspicuously deficient in phosphorus. Response to phosphorus fertilizer is less consistent in the drier western part of the region than in the more moist regions east of the Missouri River in North Dakota. Nitrogen is generally more deficient in the moister part of North Dakota than it is in eastern Montana and eastern Wyoming. Where nitrogen is deficient, little or no response is obtained from phosphate fertilizer unless nitrogen is also provided.

Erosion is a serious problem in some localities of the Northern Great Plains. Sandy soils are highly erodible because they do not contain enough silt and clay for large aggregates to form. Repeated freezing and thawing and wetting and drying result in formation of aggregates of a size susceptible to wind and water actions. Soils high in clay are most subject to this type of erosion. Areas of the different soil associations occupying surface mineable lands by States and counties are shown in table 2.

Suitability and Availability of Native Vegetation Types

Plants of the Northern Great Plains coal province are mostly such grass species as wheatgrasses, needlegrasses, grama grasses, bluestems, and fescues. Overgrazing by buffalo and later by livestock has resulted in an increase in sagebrushes and rabbit brushes in these grasslands, especially the short-grass prairies. All native grasses in the Northern Great Plains grow well under the favorable precipitation-temperature pattern. The cold-desert biome, dominated by sagebrush, and the montane-coniferous forest biome, dominated by ponderosa pine, also occur in the Northern Great Plains. Cottonwood, willow, and ash of the deciduous forest biome dominate the gully bottoms along rivers and their tributaries. Fourwing saltbush, found along the drainages, and inland saltgrass indicate alkaline or saline areas. Frequently, sand sage and prairie sandreed occupy sandy areas. Sixteen broad, but recognizable, vegetation types have been delineated in the Northern Great Plains coal province (fig. 1). Nine of these 16 vegetation types occur on surface mineable areas. They are the only vegetation types that will be considered in regard to rehabilitation potential. A brief description of these vegetation types in respect to their suitability and availability for rehabilitation is presented. To permit comparison, the corresponding Kuchler (1964) vegetation type number is also shown. Vegetation types are as follows:

Floodplain (type 1, Kuchler type 98).--This vegetation type occurs on the bottom lands and banks of major rivers and on broad floodplain terraces that have alluvial soils. It occupies sites, some highly saline, that have high water tables. The floodplain type is characterized predominantly by hardwood tree and shrub species that are poorly suitable and poorly available for rehabilitation.

Badlands (type 2, Kuchler has no type number for the Badlands).--This vegetation type occupies breaks along rivers and streams and steep south slopes of exposed shales, sandstones, and clays. Dominant plant species are arid-land shrubs and grasses associated locally with scabby ponderosa pine forests. The species that characterize this type are poorly suitable and poorly available for rehabilitation.

Short-Grass Prairie (type 3, Kuchler type 64).--This vegetation type occupies dry prairies on shallow soils in southeastern Montana and northeastern Wyoming. Dominant species are blue grama grass, western wheatgrass, and various needlegrasses. The species that characterize this type have moderately poor suitability and fair availability for rehabilitation.

Mid-Short Grass Prairie (type 4, Kuchler types 64 and 66).--This type occupies rolling prairies on loam to clay loam soils in eastern Montana. It is characterized by western wheatgrass, needle-and-thread grass and blue grama grass. These species have moderately poor suitability and fair availability for rehabilitation.

Mid-Grass Prairie (type 5, Kuchler type 66).--This type, which occurs on loamy soils in extreme eastern Montana, southwestern North Dakota, and northwestern South Dakota, contains no dominant short grass. Principal species are needlegrasses, wheatgrasses, and blue stem grasses. Most species that comprise this type are fairly suitable and have good availability for rehabilitation.

Grassland-Sagebrush (type 6, Kuchler type 56).--This vegetation type occurs on open grassland of mid and short grasses, with scattered sagebrush, and occurs on silty clay loam soils in southeastern Montana and northeastern Wyoming. Most of the species that comprise this type have good suitability and moderately good availability for rehabilitation.

Sagebrush-Steppe (type 7, Kuchler type 55).--This type is dominated by sagebrush in open grassland containing wheatgrasses and needle-and-thread on silt to silty clay loam soils. It occurs chiefly in northeastern Wyoming and most of the major species have moderately good suitability, but are relatively unavailable for rehabilitation.

Mid-Tall Grass Prairie (type 9, Kuchler type 67). This vegetation type occurs on gently rolling prairie northeast of the Missouri River in North Dakota, and is characterized by wheatgrasses, big and little bluestem grasses, and needlegrasses on loam soils of glacial till origin. Nearly all species in this type have good suitability and availability for rehabilitation.

Ponderosa Pine Forest (type 12, Kuchler type 16).--This vegetation type occurs mainly in eastern Montana and northeastern Wyoming on uplands, ridges, and north slopes that have shallow loam soils. Prominent species are ponderosa pine, snowberry, blue grasses, fescues, and June grass. These species are only fairly suitable, but have good availability for rehabilitation.

These native vegetation types and their species represent the potential for reestablishment of native plant cover on surface-mined areas where surface soil has been replaced. In some portions of the Northern Great Plains, where higher precipitation and more fertile soils occur, surface-mined lands may be restored to agricultural uses rather than to native cover types. In some instances, surface-mined lands may lend themselves to such other uses as development of parks, lakes, marshes, or woodlands. Where such opportunities exist, they should be developed, but they require careful planning of mining and post-mining activities. Except for rehabilitating agricultural lands (largely in North Dakota) and for occasional specialized reclamation opportunities, the greatest potential for rehabilitating surface-mined lands in the study area lies in using native plant species that characterize each area. Areas of different vegetation types occupying surface mineable lands by State and by county are shown in table 3.

Table 3.--*Areas of different vegetation types occupying surface-mineable lands by States and counties in the Northern Great Plains*

State and County	Vegetation type 1	2	3	4	5	6	7	9	12
	Acres								
Wyoming									
Campbell	0	0	0	0	0	176,282	96,845	0	12,416
Converse	0	0	0	0	0	42,214	0	0	2,483
Johnson	0	0	0	0	9,933	29,798	0	0	0
Sheridan	7,450	0	0	0	0	19,866	4,966	0	4,966
Weston	0	0	14,899	0	0	0	0	0	0
Total	7,450	0	14,899	0	9,933	268,160	101,811	0	19,865
Montana									
Bighorn	4,966	0	0	44,698	0	144,026	0	0	14,899
Custer	0	0	64,563	4,966	0	7,450	0	0	12,416
Dawson	0	0	0	7,450	17,382	0	0	0	0
Fallon	0	0	24,832	9,933	0	0	0	0	0
Garfield	0	49,664	0	196,173	0	0	0	0	32,282
McCone	0	4,966	0	59,597	34,765	0	0	0	0
Musselshell	0	0	0	0	0	0	0	0	9,933
Powder River	0	0	44,698	0	0	111,744	14,899	0	72,013
Richland	0	0	0	7,450	81,946	0	0	0	0
Roosevelt	0	0	0	0	17,382	0	0	0	0
Rosebud	7,450	0	0	14,899	0	76,979	0	0	44,698
Sheridan	0	0	0	0	32,282	0	0	0	0
Treasure	0	0	0	29,798	0	0	0	0	0
Wilbaux	0	2,484	0	0	42,214	0	0	0	0
Total	12,416	57,114	134,093	374,964	225,971	340,199	14,899	0	186,241
North Dakota									
Adams	0	0	0	0	49,644	0	0	0	0
Billings	0	0	0	0	22,349	0	0	0	0
Bowman	0	0	0	0	22,349	0	0	0	0
Burke	0	0	0	0	0	0	0	22,349	0
Burleigh	0	0	0	0	7,450	0	0	0	0
Dunn	0	0	0	0	22,349	0	0	0	0
Golden Valley	0	0	0	0	37,248	0	0	0	0
Hettinger	0	0	0	0	109,261	0	0	0	0
McLean	0	0	0	0	19,866	0	0	0	0
Mercer-Oliver	12,416	0	0	0	126,643	0	0	0	0
Slope	0	2,483	0	0	109,261	0	0	0	2,483
Stark	0	0	0	0	96,845	0	0	0	0
Ward	0	0	0	0	7,450	0	0	9,933	0
Williams	0	0	0	0	22,349	0	0	0	0
Total	12,416	2,483	0	0	653,064	0	0	32,282	2,483
South Dakota									
Butte	0	0	0	0	52,147	0	0	0	0
Meade	0	0	0	0	76,979	0	0	0	0
Total	0	0	0	0	129,126	0	0	0	0
TOTALS	32,282	59,597	148,992	374,964	1,018,094	608,359	116,710	32,282	208,589

DEVELOPMENT OF REHABILITATION-RESPONSE UNITS AS A CLASSIFICATION SYSTEM FOR REHABILITATION POTENTIALS ON SURFACE-MINED LANDS

In developing this report the author has assumed that--within the constraints of map scale and detail of information available--three major environmental factors influence the potential for rehabilitating surface-mined land in the Northern Great Plains: (1) the productivity and stability characteristics of surface soil materials; (2) the suitability of native plant species for plant cover reestablishment and their availability for the purpose; and (3) the amount and distribution of precipitation. The surface mineable lands in the Northern Great Plains occur in 17 soil associations, in 9 broad vegetative types, and in 7 annual precipitation zones ranging from less than 12 to more than 16 inches by 1-inch increments. If these 17 soil associations, 9 vegetative types, and 7 precipitation zones occurred together in all possible combinations, they would aggregate 1,071 different areas. All possible combinations do not occur on the surface mineable lands in the Northern Great Plains; these factors combine to delineate 86 different combinations on the ground. Thus, the surface mineable area in the Northern Great Plains can be divided into 86 different kinds of land, each with its own rehabilitation-potential characteristics. Most combinations are found in more than one location; thus, the surface mineable area of the Northern Great Plains contains a total of 146 rehabilitation-response units.

Each rehabilitation-response unit is identified by three sets of numbers (table 4). The first number, containing either two or three digits, refers to the Aandahl soil association number; the second, containing either one or two digits, refers to the vegetation type number; and the third, containing two digits, refers to the precipitation zone in which the unit is located. For example, rehabilitation-response unit 117-6-14 is a tract of surface mineable land located in Ustic Aridisol soil association 117, on grassland-sagebrush vegetation type 6, in a 14-inch-per-year precipitation zone. These combined characteristics place this particular kind of rehabilitation-response unit in east-central Campbell County, Wyoming. Presumably, regardless of location, rehabilitation-response units that have the same soil-vegetation-precipitation identifications should exhibit essentially the same response to similar rehabilitation efforts in a comparable time period. Rehabilitation-response units have been numbered from 1 through 86. The same number on more than one response unit indicates more than one tract of land in that response-unit category. All rehabilitation-response units that comprise surface mineable lands are shown by location and number in figure 2 (map, back of book). They are also tabulated in table 4 by number and acreage for States and counties. The total acreage of all rehabilitation-response units, which is the total surface mineable area in the Northern Great Plains coal province, is 2,599,913 acres, or 4,062 square miles.

Table 4.--*Kinds and areas of rehabilitation-response units on surface-mineable lands of the Northern Great Plains*

State and County	Rehabilitation-response unit				
	Identification number			Map location number	Area
	Soil	Vegetation	Precipitation		
					Acres
Wyoming					
Campbell	117	6	14	1	14,899
	117	7	16	2	27,315
	117	6	16	3	17,382
	117	7	15	4	14,899
	117	6	12	5	58,976
	117	6	11	6	35,386
	117	6	13	7	27,315
	123	6	15	9	4,966
	123	7	16	8	44,698
	123	7	15	10	9,933
	123	12	11	12	12,416
	123	6	12	13	4,966
	123	6	13	14	4,966
	123	6	14	15	7,450
Total					285,568
Converse	117	6	13	7	19,866
	117	6	14	1	7,450
	117	6	12	5	2,483
	123	6	12	13	12,416
	123	12	12	11	2,483
Total					44,698
Johnson	117	5	15	21	7,450
	117	6	15	22	9,933
	123	6	15	9	19,866
	123	5	15	20	2,483
Total					39,731
Sheridan	25	1	15	17	2,483
	25	6	15	19	19,866
	25	12	15	18	4,966
	123	1	15	16	4,966
	123	7	15	10	4,966
Total					37,248
Weston	121	3	18	23	14,899
Total					14,899
TOTAL					422,144

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Table 4.--(con.)

State and County	Rehabilitation-response unit				
	Identification number			Map location number	Area
	Soil	Vegetation	Precipitation		
					Acres
Montana					
Bighorn	25	6	15	19	17,382
	25	12	15	18	12,416
	31	6	15	26	12,416
	31	6	16	27	2,483
	31	4	15	39	4,966
	117	6	15	22	96,845
	117	1	15	40	4,966
	117	12	15	41	2,483
	123	6	15	9	14,899
	123	4	14	37	39,731
Total					208,589
Custer	31	3	15	28	32,282
	31	3	14	31	14,899
	31	6	15	26	7,450
	44	3	13	46	14,899
	44	12	13	47	2,483
	123	3	14	32	2,483
	123	12	13	44	9,933
	123	4	13	42	4,966
Total					89,395
Dawson	26	4	13	62	7,450
	26	5	13	61	4,966
	33	5	12	59	12,416
Total					24,832
Fallon	44	3	13	46	24,832
	44	4	13	48	9,933
Total					34,765
Garfield	44	4	12	53	188,723
	44	12	12	54	4,966
	184	2	12	55	49,664
	184	12	12	56	27,315
	184	4	12	57	7,450
Total					278,118
McCone	26	5	12	58	9,933
	33	5	12	59	4,966
	44	5	12	60	19,866
	44	4	12	53	54,630
	184	2	12	55	4,966
	184	4	12	57	4,966
Total					99,328

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Table 4.--(con.)

State and County	Rehabilitation-response unit				
	Identification number			Map location number	Area
	Soil	Vegetation	Precipitation		
					Acres
Montana (con.)					
Musselshell	123	12	12	11	7,450
	123	12	13	43	2,483
Total					9,933
Powder River	31	12	15	25	34,765
	31	6	15	26	9,933
	31	6	16	27	47,181
	31	3	15	28	44,698
	31	6	17	29	22,349
	31	12	16	30	34,765
	117	6	15	22	14,899
	123	12	15	24	2,483
	123	6	15	9	17,382
	123	7	15	10	14,899
Total					243,354
Richland	26	5	12	58	34,765
	26	5	13	61	9,933
	26	4	13	62	7,450
	33	5	12	59	29,798
	35	5	14	51	7,450
Total					89,395
Roosevelt	26	5	13	61	17,382
Total					17,382
Rosebud	31	6	16	27	42,214
	31	1	16	33	7,450
	31	12	16	30	27,798
	31	6	17	29	17,382
	123	12	16	35	7,450
	123	6	15	9	9,933
	123	6	16	36	7,450
	123	4	14	37	7,450
	123	4	15	38	7,450
	123	12	15	24	2,483
Total					144,026
Sheridan	23	5	13	63	12,416
	26	5	13	61	19,865
Total					32,281
Treasure	123	4	13	42	24,832
	123	4	14	37	4,966
Total					29,798

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Table 4.--(con.)

State and County	Rehabilitation-response unit				
	Identification number			Map location number	Area
	Soil	Vegetation	Precipitation		
					Acres
Montana (con.)					
Wilbaux	27	5	14	49	29,798
	33	5	14	50	4,966
	33	2	14	52	2,483
	35	5	14	51	7,450
Total					44,698
TOTAL					1,345,894
North Dakota					
Adams	30	5	16	86	42,214
	25	5	16	72	7,450
Total					49,664
Billings	24	5	15	76	22,349
Total					22,349
Bowman	24	5	15	76	4,966
	25	5	15	78	17,382
Total					22,349
Burke	19	9	15	75	22,349
Total					22,349
Burleigh	19	5	16	64	7,450
Total					7,450
Dunn	24	5	15	76	4,966
	30	5	15	77	17,382
Total					22,349
Golden Valley	27	5	14	49	29,798
	33	5	14	50	7,450
Total					37,248
Hettinger	30	5	16	86	14,899
	25	5	16	72	94,362
Total					109,261
McLean	21	5	15	67	9,933
	19	5	16	64	9,933
Total					19,866
Mercer-Oliver	19	5	16	64	22,349
	19	1	15	65	4,966
	19	1	16	66	2,483
	19	5	15	73	4,966

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Table 4.--(con.)

State and County	Rehabilitation-response unit				
	Identification number			Map location number	Area
	Soil	Vegetation	Precipitation		
					Acres
North Dakota (con.)					
Mercer-Oliver	21	5	15	67	7,450
(con.)	23	5	16	68	24,832
	25	5	16	72	12,416
	35	5	16	69	24,832
	35	5	15	70	29,798
	35	1	16	71	4,966
Total					139,059
Slope	24	5	16	85	4,966
	24	5	14	79	12,416
	24	5	15	76	17,382
	25	5	15	78	14,899
	35	5	15	70	17,382
	35	5	14	51	9,933
	35	2	14	81	2,483
	184	12	15	80	2,483
	25	5	16	72	32,282
Total					114,227
Stark	35	5	16	45	19,866
	24	5	15	76	49,664
	30	5	15	77	12,416
	25	5	16	72	14,899
Total					96,845
Ward	19	5	16	64	7,450
	19	9	16	74	2,483
	19	9	15	75	7,450
Total					17,382
Williams	19	5	15	73	2,483
	35	5	14	51	12,416
	35	5	15	70	7,450
Total					22,349
TOTAL					702,748
South Dakota					
Butte	44	5	14	82	37,248
	111	5	14	83	14,899
Total					52,147
Meade	109	5	15	84	76,979
Total					76,979
TOTAL					129,126

CLASSIFICATION OF EXISTING SURFACE MINES BY REHABILITATION-RESPONSE UNITS

Approximately 27 surface coal mines in the Northern Great Plains are either mining or are expected to mine coal in sufficient quantities to warrant concern for reclamation and rehabilitation of disturbed areas. Locations of these mines in relation to the rehabilitation-response units of the Northern Great Plains are shown in figure 2. Five of the mines shown in table 5 either are proposed or are in the developmental stage; consequently, they have no rehabilitation history.

Six of these 27 mines either have been operated in the past or are operating now (table 6); however, none of them has a firm enough history of rehabilitation to be included in this report.

Besides the six surface coal mines listed in table 6, mine 28 (the Hallett Minerals bentonite mine), is operating in Treasure County, Montana, on rehabilitation response unit 41-3-12. A rehabilitation program has been planned, but has not yet been implemented.

Either rehabilitation research or a rehabilitation-action program has been instigated for each of the remaining 16 surface coal mines and 3 large bentonite mines (table 7). Their rehabilitation experience or history will be described. The Soil Conservation Service has initiated adaptability tests of a large number of plant species on some of these mines. These studies are not yet completed. Accordingly, no attempt has been made to evaluate that testing program in this report.

These mines are on 14 different rehabilitation-response units. Thus, of the 86 rehabilitation-response units on surface mineable lands in the Northern Great Plains, results of rehabilitation research or applied rehabilitation treatments are available for only about 17 percent of the rehabilitation-response units. Fortunately, these mines are distributed over a sufficiently varied range of rehabilitation-response units to allow some interpolation of rehabilitation results.

Table 5.--*Proposed or undeveloped major surface coal mines*

State and County	Mine No.	Mining company	Rehabilitation-response unit
Wyoming			
Campbell	10	Kerr-McGee Co.	117-6-11
	7	Carter Oil Co.	123-12-14
	8	Atlantic-Richfield Co.	117-6-11
Johnson	9	Reynolds Metals Co.	117-6-15
Sheridan	6	Welch Coal Co.	25-12-15

Table 6.--*Major surface coal mines for which no rehabilitation data nor experience are available*

State and County	Mine No.	Mining company	Rehabilitation-response unit
Wyoming			
Converse	3	Best Coal Co.	123-6-10
Montana			
Musselshell	16	Reliable Coal Co.	123-12-12
North Dakota			
Adams	27	Arrowhead Coal Co.	25-5-15
Burke	24	Bonsness Coal Co.	19-9-15
McLean	25	Underwood Coal Co.	19-5-16
Stark	26	Husky-Briquetting Co.	30-5-16

Table 7.--*Coal and bentonite surface mines on which surface rehabilitation activities have occurred*

State and County	Mine No.	Mining company and mine	Rehabilitation-response unit
		COAL OPERATIONS	
Wyoming			
Campbell	1	Wyodak Resources Development Co. (Wyodak)	117-6-14
	2	AMAX Coal Co. (Belle Ayr)	117-6-13
Converse	4	Pacific Power & Light Co. (Glenrock)	123-6-14
Sheridan	5	Bighorn Coal Co. (Bighorn)	25-6-15
Montana			
Bighorn	11	Decker Coal Co. (Decker)	117-6-15
	12	Westmoreland Coal Co. (Sarpy Creek)	31-4-14
Rosebud	13	Peabody Coal Co. (Colstrip)	31-12-16
	14	Western Energy Co. (Colstrip)	31-12-16
Richland	15	Knife River Coal Co. (Savage)	26-5-13
North Dakota			
Oliver	20	Baukal-Noonan Co. (Center)	35-5-16
Mercer	21	North American Coal Co. (Zap)	35-5-16
	22	Knife River Coal Co. (Beulah)	23-5-16
	23	Consolidation Coal Co. (Stanton)	35-5-16
Burke	24	Baukal-Noonan Co. (Noonan Strip)	19-9-15
McHenry	25	Consolidation Coal Co. (Velva)	19-9-16
Adams	26	Knife River Coal Co. (Gascoyne)	25-5-15
		BENTONITE OPERATIONS	
Montana			
Carter	29	International Minerals & Chemical Co. (Carter)	111-5-14
	30	American Barroid Co. (Carter)	111-5-14
	31	Federal Minerals Co. (Carter)	111-5-14

A brief description of rehabilitation efforts and results on the surface mines listed in table 7 follows:

1. *Wyodak Resources Development Co. (Wyodak)*.--This mine is on the Wyodak seam in northeastern Wyoming. The top 10 feet of overburden is sandy and has no adverse chemical characteristics. Spoil banks have been graded to a level or gently sloping configuration. An action program was instituted to revegetate the completed areas of spoil banks. In the spring of 1972, areas were lightly disked and seeded to crested wheatgrass, green needlegrass, western wheatgrass, and fourwing saltbush. No supplemental irrigation was applied. Excellent stands were obtained by planting on spoils from both shallow and deep depths; however, vigor of stands grown on spoil banks derived from shallow depths was better. Short-term conclusions about this mine are that (1) the overburden from deep depths is not toxic, (2) spoil banks finished off with near-surface material provide better growth, (3) rehabilitation can be accomplished without irrigation, and (4) good rehabilitation success can be achieved on rehabilitation-response unit 117-6-14.

2. *AMAX Coal Co. (Belle Ayr)*.--This mine is on the Wyodak seam in northeastern Wyoming. The overburden, which consists of mixed sandstone, claystone, and shale, is quite sandy. No toxic or sterile overburden has been encountered. As at the Wyodak mine, the upper 10 feet of overburden is best for final emplacement on graded spoils. Spoils have been shaped to gentle slopes similar to the natural topography. No serious erosion problems exist. AMAX, the University of Wyoming, and the Forest Service have established successful rehabilitation plantings on this mine. AMAX and the Soil Conservation Service have initiated small-scale test rehabilitation programs. AMAX has planted most of the areas that have been rehabilitated. Approximately 400 acres, used for spoil disposal from the mine pit, have been planted to grasses, forbs, and shrubs and developed into a cattle grazing enterprise. Another 25 acres, more or less, have been planted to protect and stabilize mine spoils. The University of Wyoming has successfully established a number of grass and legume species on an experimental area of only a few acres. Similarly, the Forest Service has an experimental planting of several shrub and tree species (225 of each species), some of which have established successfully.

Among the grass and shrub species that have been successfully grown on the Belle Ayr mine are western wheatgrass, green needlegrass, tall wheatgrass, and four wing saltbush. No mulches, soil amendments, or irrigation have been used in connection with these plantings. Some have been fertilized, however.

This mine is representative of rehabilitation-response unit 117-6-13. Short-term conclusions based on results of rehabilitation efforts are that (1) grading of spoils to gentle slopes reduces or eliminates erosion of the soil surface; (2) fertilizer improves initial growth while the ground is still moist, but apparently does not enhance survival after the ground dries; (3) native and adapted introduced grasses and shrubs establish and survive well, especially where the top 10 feet of overburden has been used to finish off the spoil surface; and (4) in years of average and above-average precipitation, initial establishment of adaptable plant species should not be difficult on this rehabilitation-response unit.

4. *Pacific Power and Light Company (Glenrock)*.--Overburden at this mine consists of mixed sandstone, claystone, and shale, and is quite sandy. Toxic or sterile overburden caused by excessive sodium has been identified, but only in clay materials at great depths near the coal seams. As at the Wyodak and Belle Ayr mines, the upper 10 feet of overburden has been found to be best for final surfacing on graded spoils. The

sandy overburden strata ranging from about 10 to 60 feet in depth are also suitable, although not quite as desirable as the topmost layers for supporting plant growth. This mine has been operated since 1958. Rehabilitation activities were begun in 1964, and approximately 550 acres of spoils have been revegetated. Those areas reseeded between 1964 and 1969 did not develop completely satisfactory stands of vegetation. Beginning in 1970, the company's Environmental Group developed new and better techniques for revegetating spoils. These techniques include using such native species as western and thick-spike wheatgrasses and green needlegrass; grading spoils to slopes of less than 3:1; contour farming practices; and cross-slope disking of large amounts of straw mulch into the surface spoils. Since 1971, the company has reseeded all spoils on which unsatisfactory plant cover had developed prior to 1970. Currently, their rehabilitation program follows mining by from 6 months to a year.

The first fertilizer used by this company was an aerial application made in the spring of 1973. There has been insufficient time to evaluate its effects. In view of precipitation of less than 14 inches annually, the effects of fertilizer on plant cover development may not be as great or as apparent or likely as in a more humid climate.

In summary, the short-term conclusions from rehabilitation efforts on this mine, which is representative of response unit 123-6-14, are: (1) Grading spoils to gentle slopes reduces erosion of the soil surface and greatly enhances contour farming techniques in rehabilitation; (2) native grasses--as well as some adapted introduced ones--establish and survive very well where the top 10 feet of overburden is used to finish off the spoil surface; (3) poorer but still satisfactory establishment of vegetation can be achieved where the deeper but still sandy overburden material is used for surfacing; (4) neither fertilizer nor watering has been necessary to establish vegetation on spoils at this mine; and (5) straw mulch disked into the spoils on the contour has greatly enhanced survival and subsequent plant growth.

5. *Bighorn Coal Co. (Bighorn).*--This mine is near Sheridan, Wyoming, in rehabilitation-response unit 25-6-15. Overburden from the mine has been graded from level to grades of 2½:1. The top several feet of overburden is moderately fertile and stable. No severe surface erosion is evident. Rehabilitation work on this mine has been in progress since 1967. Planted were native grama grasses, needlegrasses, and wheatgrasses, as well as introduced crested wheatgrass. Native and introduced trees and shrubs were also planted. Rye has been an extremely successful nurse crop for new grasses. When planted in the spring, it sprouts in from 1 to 3 weeks. During the first year, it covers most of the soil and protects it against erosion. The Bighorn mine's Plachek plot, the first planted in 1967, supports a good stand of perennial grasses, as do all areas planted subsequently. Application of phosphorus and nitrogen fertilizer to newly regraded spoils finished off with topsoil is an excellent boost to new plant growth on this mine, as long as the soil is moist. Several tree species grow well in the area if irrigation water is available at the time of planting. Repeated watering during the first growing season enables newly planted trees to establish adequate root systems. The survival rate is substantially reduced in the absence of water.

The Bighorn mine encroaches upon the Tongue River, where the river has cut through a series of steep hills. Part of the area has been reshaped to create a lake fed by the Tongue River. Peter Kiewits Construction Co., owner of the mine, and the Wyoming State Parks Department coordinated this reclamation and rehabilitation effort. A State Park will be finished at about the same time that mining is completed. Conclusions drawn from 6 years of rehabilitation efforts at this mine are (1) a nurse crop of rye provides quick protection against surface soil erosion and enhances establishment of perennial vegetation; (2) good stands of perennial grasses and a variety of trees and shrubs can usually be established on this rehabilitation-response unit; (3) establishment of grasses does not require supplemental irrigation, but better survival of trees and shrubs depends on periodic watering during the first year. Fertilizing, especially with phosphorus and nitrogen, improves the rate of plant growth while the soil is still moist.

11. *Decker Coal Co. (Decker).*--This mine is at Decker, Montana, in rehabilitation-response unit 117-6-15. Soils at the Decker mine contain excess soluble salts and exchangeable sodium. Surface evaporation has drawn sodium salts to the surface. Most vegetation in the area, including blue grama grass, needlegrass, and western wheatgrass, are drought-, saline-, and alkaline-tolerant species.

Surface soil was removed and stockpiled separately from the main overburden piles. After mining, the overburden piles were regraded to a level or gentle slope, not exceeding 5:1, and finished off with topsoil. After mining, the configuration of the landscape is similar to that before mining. In most places, conventional farm machinery could be used for mine-rehabilitation activities.

Rehabilitation research at the Decker mine was begun in 1971 by the Montana Agricultural Experiment Station. Initially, the major emphasis was placed on overburden analysis to evaluate the seriousness of the saline-alkaline problem. More than 70 plant species were seeded. In the fall of 1972, the Intermountain Forest and Range Experiment Station established a completely randomized block experiment on Decker mine spoils to test the effects of irrigation versus no irrigation, fertilizer versus no fertilizer, and mulch versus no mulch on three mixtures of all native, native and pasture, and all pasture grasses. No evaluation of the Montana Agricultural Experiment Station plantings is available. First-year results of the Intermountain Station's plantings indicate that the best native species are western wheatgrass and green needlegrass. The best responding introduced species are smooth brome, winter rye, and tall wheatgrass. Gypsum appears to mitigate the adverse effects of saline-alkaline soils on these plants. Mulching enhances early germination and survival by conserving soil moisture. Phosphorus-nitrogen fertilizer, mulch, and irrigation separately increased vegetative growth and production. Together, fertilizer, mulch, and irrigation resulted in even greater increases in production. Topsoiling, alone, produced good stands of vegetation, but not as good as those developed with mulch and fertilizer. At the end of the first growing season, European sage had survived and grown well; it was the best of the planted shrubs.

Short-term conclusions from rehabilitation-research efforts on this mine are that vegetation can be reestablished on rehabilitation-response unit 117-6-15. Results show that: (1) establishment of vegetation is likely to be fair to poor in the absence of mulching to conserve soil moisture, phosphorus and nitrogen to stimulate growth, and irrigation and gypsum to counteract the adverse physiological effects of large amounts of sodium; (2) introduced grass species produce the greatest volume during the first year, but native species produce surprisingly more than had been expected; and (3) more research time is needed on the Decker mine before the stability and permanency of planted vegetation can be evaluated.

12. *Westmoreland Resources (Sarpy Creek).*--This mine is a new one near Hardin, Montana, in rehabilitation-response unit 31-4-14. The area is gently sloping. Soil texture varies from medium to moderately coarse. Adequate topsoil is available to be stockpiled and used to cover spoil surfaces during rehabilitation. Native vegetation is typical of vegetation type 4, which consists of green needlegrass, western and blue bunch wheatgrasses, sideoats grama, needle-and-thread, Idaho fescue, skunkbush sumac, chokecherry, hawthorne, snowberry, and, on some areas, ponderosa pine.

Overburden analyses show no significant differences between raw spoil materials and surface materials in respect to either sodium or salinity hazard. At this writing (early 1974), 1973 fall plantings have not yet germinated and developed. No problem is apparent in soil toxicity, vegetative suitability, or precipitation characteristics that would prevent establishment of plant cover on this mine. The limiting factor is likely to be rather mediocre natural productivity of this soil.

13 & 14. *Peabody Coal Co. and Western Energy Co. (Colstrip).*--These two mines are located at Colstrip, Montana, in rehabilitation-response unit 31-12-16. Soil texture

varies from moderately fine to coarse. Vegetation typifies the mid-short grass prairie, but scattered stands of ponderosa pine occur. Surface soil materials are available on both mines in ample quantities to cover less desirable overburden materials.

Both Peabody and Western Energy Co. have cooperated extensively in a research program with the Montana Agricultural Experiment Station. Using different site-preparation methods, scientists from Montana State University have screened many species of grasses, shrubs, and trees for adaptability to conditions on these two mines. Two seams of coal are being mined at the Peabody site. During early mining activity, a toxic blue-gray shale between the seams was deposited on the surface, creating difficulties in establishing vegetation. Mining techniques have since been changed to correct this situation. Rehabilitation research has been underway longer at Colstrip than at any other site in Montana. Short-term (3-year) results indicate that successful rehabilitation of response unit 31-12-16 with a variety of grasses, shrubs, and trees is highly probable. The most limiting major factor is the inherent mediocre productivity of soil association 31.

15. *Knife River Coal Co. (Savage)*.--This mine, near Savage, Montana, is on rehabilitation-response unit 26-5-13. Topography is gently sloping with shallow-to-deep, well-drained soils. Texture of the soil is loam to sandy loam. Topsoil materials range up to 2 feet in thickness and--if stockpiled--are adequate for finishing graded spoils during reclamation. Similarly, the sandy, yellowish-brown silt loam, and fine sandy loam material of the overburden beneath the topsoil are satisfactory for finishing graded spoil surfaces. Gray clay or silty clay above and between the coal seams are toxic and should be buried during the mining operation. Native vegetation is mid-grass prairie, mostly western and slender wheatgrasses, green needlegrass, and prairie sand reed.

Several years ago, the Knife River Coal Co. began grading old spoils to a gentle grade and planting them. The company has cooperated with the Montana Agricultural Experiment Station and the Soil Conservation Service in several experimental plantings. Excellent stands of both introduced and native grasses have been obtained, and several species of trees have been established successfully. This success was obtained on spoils that were leveled to 3:1 slopes. Standard seeding and planting techniques and commonly available plant materials were used. Much of this success can be attributed to the good productivity and stability characteristics of soil association 26, as well as to the rich and vigorous flora of the mid-grass prairie.

20. *Baukal-Noonan (Center)*.--This mine is a few miles southeast of Center, North Dakota, on rehabilitation-response unit 35-5-16. The terrain is rolling, the soil is loamy, and the overburden is sandy and shaley. Spoils on this mine have been unusually well shaped and blended into the natural landscape.

Research has shown that the overburden on lignite coal deposits, which characterize most of North Dakota, contains substantially higher quantities of sodium than does the overburden on the sub-bituminous coal deposits in eastern Montana and northeastern Wyoming (Sandoval and others 1973). This difference has given rise to more serious sodium-toxicity problems in connection with rehabilitation efforts on surface mines in North Dakota than has been experienced on most mines in Montana or Wyoming. Whereas sodium content of overburden from Baukal-Noonan's (Center) North Dakota mine is somewhat higher than that encountered on the Montana and Wyoming mines, it is still substantially less than that on any other major North Dakota mine. Accordingly, overburden on this mine forms a relatively favorable planting medium, limited only by the rather mediocre inherent productivity of soil association 35. A variety of cool-season grasses and legumes have been planted on this mine, including western wheatgrass, big and little bluestem, sweet clover, and crown vetch. Success of various plantings, including those areas drilled in the fall of 1972, is generally good. This soil association has poor stability characteristics, and deep rilling has occurred where spoil slopes were too

steep for cross-slope finish work. Where spoils have been drilled upslope and downslope, a high erosion hazard exists. Level or gentle slopes and cross-slope cultivation appear to be essential for permanently stable reclamation of this rehabilitation-response unit.

21. *North American Coal Co. (Zap)*.--This mine, near Zap, North Dakota, is on rehabilitation-response unit 35-5-16. Overburden, which resulted from mining here, has been shown to have the second highest average sodium content of eight major mines sampled in North Dakota. Spoils from this mine have the highest sodium-adsorption ratio and pH of any mine for which records are available in the Northern Great Plains (Sandoval and others 1973). The fine-textured spoil materials consist largely of montmorillonitic clay, are low in natural organic matter, and are highly toxic to vegetation.

Overburden from this mine, except that within approximately 10 feet of the original surface, presents a tremendous rehabilitation problem if placed on the surface of graded spoils. Analyses of North Dakota overburden by depth increments indicate that the sodic nature of the spoils increases with depth within the feasible depth range for surface mining. Experience on this mine indicates that, over a period of several years, adsorbed sodium in the mine spoils can be reduced by a chemical amendment (gypsum) or circumvented by a surface layer of soil. Little success has been achieved in rehabilitating raw spoils originating from deep, sodic layers. The dispersing effect of sodium renders the spoil material highly impermeable and erodible.

Where graded spoils have been finished off with overburden from shallow depths, immediately fertilized with phosphorus, treated within 2 years with nitrogen, together with vegetative mulch disked into the spoil surface, grass production has increased as much as 1,000 percent compared to the production on raw spoils.

On this mine and others that have similar adverse spoil characteristics, further research is needed to overcome toxicity problems before these spoils can be successfully and directly rehabilitated. Where shallow nontoxic overburden or surface soil can be used to finish spoil surfaces, immediate and successful rehabilitation to midgrass prairie or, in some cases, to cultivated grain crops, can be achieved.

22. *Knife River Coal Co. (Beulah)*.--This mine is near Beulah, North Dakota, in rehabilitation-response unit 23-5-16. Overburden materials on this mine have essentially the same sodium and pH characteristics as those in overburden on the North American mine at Zap. Little real success has been experienced in attempts to rehabilitate raw surface spoils originating from deep levels in this mine. On the other hand, attempts to rehabilitate spoils from within approximately 10 feet of ground surface or spoils dressed with surface soil by using both introduced and native grasses and legumes have been successful. One reason for this success is the inherent good stability and productivity characteristics of soil association 23.

23. *Consolidation Coal Co. (Glenharold)*.--This mine, near Stanton, North Dakota, is in rehabilitation-response unit 35-5-16. The soil, native vegetation, and precipitation characteristics of this mine are similar to the North American mine at Zap; however, the terrain is considerably more steep and hilly. Soils are loamy, but shallower because of the steeper topography. Overburden is dominantly grayish-white, and the surface dries hard after being wet, indications of high-sodium content. Tests of overburden at this mine confirm that the sodium content is toxically high, although not as high as in the Knife River mine at Beulah or in the North American mine at Zap (Sandoval and others 1973). Soil association 35 has poor stability characteristics; these are reflected on the steeper spoil slopes where rilling and gullying have occurred.

Where overburden from shallow depths or topsoil has been used to finish the surface of graded spoils, good rehabilitation results have been achieved. Mined areas are now being graded to gentle slopes, disked, and seeded to native cool-season grasses. The Consolidation Coal Co. has treated about 80 acres of raw spoils in this manner.

They have replaced topsoil on a smaller acreage and grown wheat. The company and the Soil Conservation Service have planted a variety of shrubs and trees, to evaluate their suitability for use in rehabilitating these kinds of areas. Species being tested include Russian olive, caragana, and prairie rose. About 90 percent of these species have survived. Where problems associated with high-sodium spoils have been circumvented, vegetation has become so well established that many areas appear to be undisturbed.

24. *Baukal-Noonan (Noonan Strip)*.--This mine is near Larsen, North Dakota, in rehabilitation-response unit 19-9-15. Coal from deep levels of this mine has the highest sodium content of any sampled in North Dakota (Sondreal and others 1968); consequently, it is postulated that the adjacent overburden is also high in sodium and is probably toxic for rehabilitation purposes when left on the surface of graded spoils. Surface soil from soil association 19 on this mine has good stability and productivity. Rehabilitation experience here is similar to that already noted on other North Dakota mines: little success on raw spoils from deep levels; more success on spoils from shallow depths; and most success where surface soil has been removed and then replaced as a finish for graded spoils.

25. *Consolidation Coal Co. (Velva)*.--This mine is near Velva, North Dakota, in rehabilitation-response unit 19-9-16. Tests on 10 major surface mines in the Northern Great Plains indicate that although the average sodium content of overburden from this mine is substantially greater than that in the Montana-Wyoming area, it is still only about half the sodium content encountered on most surface mines in North Dakota (Sandoval and others 1973). Spoils on this mine have been graded to gentle slopes. The soil is stable, and regraded spoils show little erosion. Rehabilitation success has not been good on raw spoils originating from deep overburden. However, rehabilitation efforts on shallow overburden materials or on surface soil-dressed spoil areas seeded with wheatgrasses, bluestems, and legumes have been successful.

26. *Knife River Coal Co. (Gascoyne)*.--This surface mine is at Gascoyne, North Dakota, in rehabilitation-response unit 25-5-15. Surface soils in this rehabilitation-response unit and on this mine are productive and stable. The soil is loamy and the terrain is level to gently rolling. Coal is at a relatively shallow depth, which necessitates removal of less than 50 feet of overburden. Sodium should not present a serious problem. Accordingly, tests show that the average sodium content is less than that from any other North Dakota mine tested (Sondreal and others 1968). The Knife River Co. began reclamation work in 1971. Some spoils have been reshaped to undulating topography. Cool-season grasses have been seeded and are establishing successfully.

29. *International Minerals and Chemical Co.;*

30. *American Barroid Co.;* and

31. *Federal Minerals Co. (Alzada, Montana)*.--

These three bentonite mines are located in rehabilitation-response unit 111-5-14. The topography is nearly level to gently sloping. Soil texture varies from claypan spots to sandy loams. Little weathering or soil development has occurred on pan spots, and surface materials for reclamation are not available from these sites. Most of the area has medium-textured soils supporting a good cover of western wheatgrass, needle-and-thread, prairie sand reed, and other desirable species. Some bur oaks occur on these sites. Such sites can provide weathered soil material necessary for reclaiming mined areas. Reclamation activities on these mines include the placement of about 4 inches of surface soil over all disturbed areas. This has been sufficient to support good seeded stands of grasses, mostly western wheatgrass, green needlegrass, and crested wheatgrass. The raw overburden is usually composed of saline clays, and stands do not become well established unless these materials are dressed with surface soil. The companies in this area have been cooperating with the Soil Conservation Service Plant Materials program to evaluate a variety of plant materials for possible use in revegetating mine spoils.

IMPACTS OF DEVELOPMENT OF THE COAL RESOURCE ON SURFACE REHABILITATION

To this point, this report has been concerned with descriptions of soil associations, vegetation types, and precipitation characteristics that combine to delineate different rehabilitation-response units on the surface mineable lands of the Northern Great Plains. The remainder of the report analyzes and summarizes the degree of potential success that might be expected in attempting to reclaim and revegetate different rehabilitation-response units.

Rating Criteria for Ranking Response Units According to Their Rehabilitation Potentials

Ranking of rehabilitation-response units according to their rehabilitation potentials depends upon combined ratings of soil productivity and stability, vegetation suitability and availability for rehabilitation, and amount and distribution of annual precipitation. Each of these soil, vegetation, and precipitation characteristics was rated on a descriptive-numerical scale as follows: very good (+9), good (+6), fairly good (+3), fair (0), fairly poor (-3), poor (-6), and very poor (-9).

Soil association productivity and stability ratings.--The productivity and stability of each surface mineable soil association in the Northern Great Plains was rated by means of the scale described above. Information concerning the productivity and stability of the soil associations was obtained from Aandahl's (1972) description of soil associations of the Northern Great Plains. These ratings are shown in table 8. Also presented is a combined rating for each soil association, obtained by averaging productivity and stability ratings. These combined ratings show that soil associations 19 and 25 (each rated +8) are the most productive and stable of these soil associations. Combined ratings also show that soil association 123 (rated -8) and soil associations 121 and 184 (each rated -9) are the least productive and most erodible of the 17 soil associations.

Vegetation type suitability and availability ratings.--The suitability of major native plant species in each of the nine surface mineable vegetation types and their availability for rehabilitation purposes were also rated. These two ratings were averaged to provide a single combined suitability-availability rating of major species for rehabilitation in each of these vegetation types. These ratings are presented in table 9. They show that the mid-tall grass prairie has the most suitable and available plant species for successful rehabilitation. They also indicate that the Badlands offer the poorest chance for rehabilitation; however, with the exception of the Badlands, all vegetation types contain some plant species that are suitable and available for rehabilitation purposes.

Table 8.--*Relative ranking of soil associations in terms of productivity and stability*

Soil association No.	Productivity rating	Stability rating	Combined rating
19	+6	+9	+8
23	+6	+6	+6
25	+9	+6	+8
26	+6	+6	+6
27	+3	+3	+3
30	+3	+3	+3
31	0	-6	-3
33	0	-6	-3
34	0	-6	-3
35	0	-9	-5
44	-3	-3	-3
109	-9	0	-5
111	-6	-3	-5
117	-6	0	-3
121	-9	-9	-9
123	-9	-6	-8
184	-9	-9	-9

Table 9.--*Relative ranking of vegetation types in terms of suitability and availability of plant species for rehabilitation*

Vegetation type	Type No.	Suitability rating	Availability rating	Combined rating
Floodplain	1	-6	-3	-5
Badlands	2	-9	-9	-9
Short grass prairie	3	-3	0	-2
Mid-short grass prairie	4	-3	0	-2
Midgrass prairie	5	0	+6	+3
Grassland-sagebrush	6	+6	+3	+5
Sagebrush steppe	7	+3	-3	0
Mid-tall grass prairie	9	+9	+9	+9
Ponderosa pine forest	12	0	+6	+3

Precipitation amount and seasonal distribution ratings.--The amount and seasonal distribution of annual precipitation on surface mineable lands of the Northern Great Plains were rated by means of the descriptive-numerical rating scale. These two ratings were averaged to provide a combined precipitation rating. In table 10, as might be expected, these ratings show that areas that have more than 16 inches of annual precipitation have the best potentials for rehabilitation; those areas that have less than 12 inches have the poorest potentials.

Table 10.--*Relative ranking of precipitation zones in terms of annual amounts and seasonal distribution*

Precipitation zone	Amount rating	Distribution rating	Combined rating
<12	-9	-9	-9
12	-6	-6	-6
13	-3	-3	-3
14	0	0	0
15	+3	+3	+3
16	+6	+6	+6
>16	+9	+9	+9

Rehabilitation Potential Rankings of Response Units

Combined ratings of soil, vegetation, and precipitation characteristics must be translated into one rehabilitation-potential ranking for each kind of rehabilitation-response unit on surface mineable lands in the Northern Great Plains; consequently, the combined rating values of the appropriate soil association (table 8), vegetation type (table 9), and precipitation zone (table 10) comprising each rehabilitation-response unit were added together algebraically and averaged. This process provided a ranking number for each rehabilitation-response unit that had a potential value of from +9 to -9. These ranking numbers indicate *the relative degree of ease or difficulty* (potential) that should be anticipated in attempting to rehabilitate *a unit area* of surface-mined land of given soil, native vegetation, and precipitation characteristics. These ranking values for all response units range from +6 to -5, an indication that none of the rehabilitation-response units exhibits either the best or the worst potential for rehabilitation.

The total area of each kind of rehabilitation-response unit in each State and county of the Northern Great Plains coal province is shown in table 4. The area of each kind of rehabilitation-response unit to be mined in each of five sample areas was calculated from the tonnage production figures determined for each of three coal development forecasts during three time frames.[2]

[2] Unpublished report of the Northern Great Plains Resource Study, U.S. Dep. Interior. The three coal resource development forecasts assumed in this report are (1) base forecast, which is continued development of the coal resource, including coal for exports and energy-conversion facilities, at about the same rate as prevailed in 1972; (2) most probable forecast, which is development at a rate several times greater than that of the base forecast; and (3) extensive forecast, which is development at the highest rate that is physically and economically feasible. The three time frames are the periods 1972 to 1980, 1980 to 1985, and 1985 to 2000.

Table 11.--*Rehabilitation potential rankings weighted by areas that will be surface mined under each of three forecasts of development of the coal resource and three time frames*[1]

Coal resource development forecast	By the year	Campbell County	Bighorn County	Rosebud County	Mercer-Oliver Counties	All other counties	Northern Great Plains total
Base	1980	+48	+192	+1,086	+5,483	0	+6,809
	1985	-2,712	+1,252	+2,781	+10,663	+4,155	+16,139
	2000	-10,991	+4,432	+7,866	+26,203	+17,820	+45,330
Most probable	1980	+48	+192	+1,086	+5,483	0	+6,809
	1985	-2,712	+2,280	+2,781	+10,663	+4,155	+17,167
	2000	-18,881	+14,355	+19,491	+36,808	+64,230	+116,003
Extensive	1980	+48	+192	+1,086	+5,483	0	+6,809
	1985	-2,409	+3,200	+4,176	+31,873	+34,375	+71,215
	2000	-28,283	+25,400	+52,506	+121,148	+207,385	+378,156

[1]Degree ratings X area mined.

Table 12.--*Surface-mined areas that will require rehabilitation under each of three forecasts of development of the coal resource and three time frames*

Coal resource development forecast	By the year	Campbell County	Bighorn County	Rosebud County	Mercer-Oliver Counties	All other counties	Northern Great Plains total
		Acres					
Base	1980	56	96	1,605	2,599	0	4,356
	1985	2,036	1,276	4,900	5,999	900	15,111
	2000	7,977	4,816	14,785	16,199	3,840	47,617
Most probable	1980	56	96	1,605	2,599	0	4,356
	1985	2,341	1,533	4,900	5,999	900	15,673
	2000	12,287	9,018	22,690	26,804	18,330	89,129
Extensive	1980	56	96	1,605	2,599	0	4,356
	1985	2,341	1,993	6,295	13,069	8,870	32,568
	2000	25,890	13,528	43,975	54,584	57,110	195,087

Table 13.--*Average weighted rehabilitation-potential rankings for each of three forecasts of development of the coal resource and three time frames*

Coal resource development forecast	By the year	Campbell County	Bighorn County	Rosebud County	Mercer-Oliver Counties	All other counties	Northern Great Plains total
Base	1980	+0.86	+2.00	+0.68	+2.11	--	+1.56
	1985	-1.33	+0.98	+0.57	+1.78	+4.62	+1.07
	2000	-1.38	+0.92	+0.53	+1.62	+4.64	+0.95
Most probable	1980	+0.86	+2.00	+0.68	+2.11	--	+1.56
	1985	-1.16	+1.49	+0.57	+1.78	+4.62	+1.10
	2000	-1.54	+1.59	+0.86	+1.37	+3.50	+1.30
Extensive	1980	+0.86	+2.00	+0.68	+2.11	--	+1.56
	1985	-1.03	+1.61	+0.66	+2.44	+3.88	+2.19
	2000	-1.09	+1.88	+1.19	+2.22	+3.63	+1.94

The area value and rehabilitation-potential ranking value of each rehabilitation-response unit were multiplied together for each of the three time frames within each of the three coal forecasts. Essentially, this means that rankings, which indicate the relative potential for rehabilitating a unit area of a given response unit, have been weighted by areas (acres that need to be mined to meet the coal production requirements of each forecast). The algebraic totals of these weighted rankings are summarized in table 11. For purposes of comparison, only surface-mined area values are listed in table 12. Finally, the weighted rankings (table 11) are divided by the area-mined values (table 12), which provides the *average* weighted rehabilitation-potential rankings of the five sample areas for each coal-development forecast and each time frame. These average weighted rehabilitation-potential rankings are summaried in table 13.

Implications of Response Unit Rankings for Rehabilitation of Surface Mines in the Sample Counties and Other Areas

Inspection of the rehabilitation-potential rankings weighted by areas that will be surface mined (table 11) reveals that rehabilitation-response units that characterize Mercer and Oliver Counties in North Dakota collectively have a much higher potential for successful rehabilitation than do those in the other sample counties; soils are more productive, vegetation types more suitable, and precipitation higher in Mercer and Oliver Counties than in the other sample areas. The weighted rehabilitation-potential rankings (table 11) also show that Rosebud County, Montana, has the next best potential for successful rehabilitation, followed by Bighorn County, Montana, and Campbell County, Wyoming. The poorest rehabilitation potential, recorded for Campbell County, results from a combination of poorly productive soils, vegetation types that have fewest suitable and available species, and the lowest precipitation in the Northern Great Plains coal province. Those areas of the Northern Great Plains coal province (All other counties, tables 11, 12, and 13) outside the boundaries of sample counties exhibit rehabilitation-potential rankings nearly as good and, in some cases, better than those of Mercer and Oliver Counties.

As might be expected, the rehabilitation-potential rankings (table 11) become larger in either a positive or negative direction as the coal-development forecast shifts from base to most probable to extended (see footnote 1). An exception occurs up to the year 1980 because the kinds of rehabilitation-response units and the areas thereof to be mined in that time frame are the same for all three development forecasts.

Table 12 reveals that the surface-mined areas requiring rehabilitation will increase as coal development shifts from base to most probable to extended and as the time frame moves from year 1980 to 1985 to 2000. In themselves, these increases in acreages to be mined imply an increasingly larger rehabilitation job, regardless of location.

The average weighted rehabilitation-potential rankings are presented in table 13. These values reveal information similar to that in table 11; however, the masking effect caused by differences in the areas to be mined has been removed. Values in table 13 reveal several kinds of important information:

1. Throughout the Northern Great Plains coal province, and especially in the sample counties, the average potential for successfully rehabilitating surface-mined lands increases with a shift from base to most probable to extensive coal-development forecasts. Accordingly, as the intensity of surface mining increases, progressively more mining will be done on rehabilitation-response units that have high rehabilitation potential rankings than will be done on those that have low ones. In the remainder of the region, the average weighted rehabilitation-potential rankings decrease

with intensification of mining activity. This decrease indicates that with intensified development of the coal resource in these areas, progressively more response units of low rehabilitation potential will be mined. Nevertheless, even with intensified development, average potentials for rehabilitation in these areas are higher than in any of the sample county areas.

2.--The highest average weighted rehabilitation-potential rankings occur on regional areas outside sample county areas. The Mercer and Oliver County areas have the highest rankings of the sample counties, followed in decreasing order by Bighorn, Rosebud, and Campbell Counties. The lowest rehabilitation-potential rankings, which average out to be negative values, occur in Campbell County.

3.--Within the base-development forecast, each sample county exhibits a decrease in average rehabilitation-potential rankings as the time frame shifts from 1980 to 1985 to 2000. In other words, the moderate increase in mining intensity associated with the changing time frame in the base-development forecast will result in the mining of a higher proportion of rehabilitation-response units of low rehabilitation potentials. Except for sample counties, virtually no mining development is scheduled prior to 1980, and the average rehabilitation-potential rankings are about the same for 1985 and 2000.

4.--Within the most probable development forecast, a decrease in the average rehabilitation-potential ranking of each sample county occurs between 1980 and 1985. Essentially, this decrease is similar to that occurring over the same time frame in the base-development forecast. However, between the years 1985 and 2000, a further continued decrease in the average rehabilitation-potential rankings occurs only in Campbell, Mercer, and Oliver Counties, and in regional areas outside sample counties. In Bighorn and Rosebud Counties, average rehabilitation-potential rankings based on the most probable development forecast, will increase from 1985 to 2000. This increase indicates that current scheduling of mining activities in these two counties includes more rehabilitation-response units of high-rehabilitation potential than of low.

5.--Within the extensive development forecast, the average rehabilitation-potential ranking for Campbell County decreased throughout the three time frames. In Bighorn and Rosebud Counties, rehabilitation-potential rankings decreased from 1980 to 1985, but increased again between 1985 and 2000. On the other hand, rehabilitation rankings for Mercer and Oliver Counties increased from 1980 to 1985, but decreased between 1985 and 2000. Although rehabilitation-potential rankings for regional areas outside sample counties were the highest in the entire study area, they decreased between 1985 and 2000. These increases and decreases in rehabilitation-potential rankings indicate differences in relative ease of rehabilitating surface-mined lands. Differences result from the sequential order in which rehabilitation-response units of better-than-average and poorer-than-average potentials for rehabilitation are scheduled for mining. Comparisons such as have been made here could be utilized to restructure the development forecasts. Such restructuring could establish a more uniform distribution of rehabilitation potentials with respect to time; and, hence, a more uniform rehabilitation effort throughout any coal-development period for any given portion of the Northern Great Plains.

Comparison of Rehabilitation-Potential Rankings From Actual Rehabilitation Efforts and From Classification of Response Units

Table 7 lists 16 coal and 3 bentonite mines for which descriptive information exists as to relative success of past rehabilitation efforts. Accordingly, descriptive rankings of *actual* rehabilitation success at these mines were compared with the

rehabilitation-potential rankings of the response units in which these mines are located (table 14). The numerical equivalents of the descriptive rankings of actual rehabilitation success on these mines were compared with the rankings of rehabilitation-response units. Comparisons reveal that the rankings of potential-rehabilitation ease on the rehabilitation-response units in which the mines are located are probably somewhat conservative. They indicate a rehabilitation-potential ranking slightly lower than the ranking of actual rehabilitation success achieved on these mines. Notwithstanding, this sample of 19 mines (some of which have been subjected to rehabilitation efforts for only a short time) is sufficiently small that alteration of the predicted rehabilitation-potential rankings to conform to the actual rehabilitation success rankings is not yet warranted. Furthermore, with few exceptions, predictive rankings are close enough to actual rankings that they can be used conservatively with confidence.

Table 14.--*Comparison of rehabilitation potential rankings from actual rehabilitation efforts and from classification of rehabilitation-response units*

Mine No.	Mining company and mine	Rehabilitation-response unit	Rehabilitation potentials: From actual rehabilitation: Descriptive	Rehabilitation potentials: From actual rehabilitation: Numerical	Rehabilitation potentials: From classification rankings: Numerical
		COAL OPERATIONS			
1	Wyodak Resources Development Co. (Wyodak)	117-6-14	Good	+6	+1
2	AMAX Coal Co. (Belle Ayr)	117-6-13	Fairly good	+3	0
4	Pacific Power & Light Co. (Glenrock)	126-6-14	Fairly good	+3	-1
5	Bighorn Coal Co. (Bighorn)	25-6-15	Good	+6	+5
11	Decker Coal Co. (Decker)	117-6-15	Fairly good	+3	+2
12	Westmoreland Coal Co. (Sarpy Creek)	31-4-14	Fairly poor	-3	-2
13	Peabody Coal Co. (Colstrip)	31-12-16	Fairly good	+3	+2
14	Western Energy Co. (Colstrip)	31-12-16	Fairly good	+3	+2
15	Knife River Coal Co. (Savage)	26-5-13	Good	+6	+2
20	Baukal-Noonan Co. (Center)	35-5-16	Fairly good	+3	+1
21	North American Coal Co. (Zap)	35-5-16	Fairly good	+3	+1
22	Knife River Coal Co. (Beulah)	23-5-16	Good	+6	+5
23	Consolidation Coal Co. (Stanton)	35-5-16	Fairly good	+3	+1
24	Baukal-Noonan Co. (Noonan Strip)	19-9-15	Very good	+9	+7
25	Consolidation Coal Co. (Velva)	19-9-16	Very good	+9	+8
26	Knife River Coal Co. (Gascoyne)	25-5-15	Good	+6	+5
		BENTONITE OPERATIONS			
29	International Minerals & Chemical Co. (Carter)	111-5-14	Fair	0	-1
30	American Barroid Co. (Carter)	111-5-14	Fair	0	-1
31	Federal Minerals Co. (Carter)	111-5-14	Fair	0	-1

CONSTRAINTS AND LIMITATIONS ON REHABILITATION

Relatively little experimentation and research have been directed to the problem of rehabilitating lands being mined for coal in the Northern Great Plains. Whereas much is known about revegetating western rangelands, comparatively little is known about rehabilitation of mine spoils. Actual rehabilitation efforts have been applied on relatively few mine sites. Perhaps the most important single point emerging from this study of surface-rehabilitation potentials is that the potential for rehabilitating surface-mined land in the Northern Great Plains is extremely site specific. The general rehabilitation potential can be judged on the basis of climatic, soil, and vegetative site components, but each site will also have its particular microclimate in terms of specific physiographic, biotic, and hydrologic components. These components influence the potential for rehabilitation of a specific site. Finally, what is done and how a site is prepared for rehabilitation also influence the rehabilitation potential. These macrosite and microsite components, as well as the measures employed to effect rehabilitation, inherently impose constraints and limitations on the rehabilitation of some sites. A brief summary of constraints on and limitations to successful rehabilitation of surface-mined sites in the Northern Great Plains follows:

1. *Macroclimate.*--Without question, local climate is the most important single parameter in assessing potential-rehabilitation success. Furthermore, the most important single climatic element influencing this success is the amount and distribution of precipitation. Assuming that approximately 10 inches of annual precipitation is the minimum amount of water needed to sustain revegetation, most surface-mined sites that receive 10 inches or less annual precipitation cannot be mapped accurately; adequate precipitation records are lacking for most such mining sites, and the nearest weather station may be many miles removed.

Variation of the annual precipitation about the mean is extremely important to revegetation success. Droughts severe enough to almost wreck the range livestock industry in the Northern Great Plains have occurred and, no doubt, will occur again. Potentials for successful rehabilitation during such droughts would be far less than those during years of average or above-average precipitation. Little site-specific analytical work has been done on precipitation variation in the Northern Great Plains.

2. *Microclimate.*--Most surface mineable lands in the Northern Great Plains are characterized by relatively gentle topography. In many instances, spoil piles left after mining constitute rougher topography than existed before mining. The configurations into which such spoil piles are shaped by heavy grading machinery can substantially influence the microclimate of each surface-mined site. Steepness of slope, roughness of surface, and direction of aspect in respect to insolation and wind can all be affected by the land-reshaping plans and measures employed.

3. *Availability of suitable plant materials.*--The author of this report assumes that unless some other rehabilitation objective is defined, the primary objective of rehabilitation on surface-mined lands in the Northern Great Plains is to establish a protective cover of durable plants, predominantly native species adapted to and characteristic of these areas before mining. Accordingly, tall-, mid-, and short-grass prairie species, some shrubs, and a few trees are the plants chiefly used to rehabilitate these surface-mined lands. Surface mineable lands in the North Dakota portion of the study area are characterized by a rich mixture of tall- and mid-grass prairie species, the seeds of which usually are commercially available in quantity. The drier portions of the study area, which are in northeastern Wyoming and eastern Montana, are characterized by short-grass prairie species that sometimes occur with dryland shrubs. These short grasses are not nearly as available commercially as are species in moister parts of the study area. A supply of seeds from these dryland species must be developed if they are to be available in sufficient quantities for rehabilitation of lands to be surface mined.

4. *Site and seedbed preparation.*--More than a half century of range revegetation and farming experience in the Northern Great Plains has resulted in development of site- and seedbed-preparation techniques that can be used successfully to revegetate disturbed landscapes. Minimum requirements would certainly include grading of spoils to short lengths of gentle-to-moderate slopes and placement of the highest site-productive overburden strata on the surface. Equally essential is the tillage accomplished by established agricultural procedures of spoil surface materials to a satisfactory condition for seeding and planting. Failure to shape and till the land satisfactorily can result in greatly reduced rehabilitation success or in complete failure.

5. *Planting procedures.*--Suitable planting procedures that provide for seed coverage by surface spoil materials at the proper depths is essential for successful revegetation of surface-mined land. Seeds cannot simply be thrown upon bare ground without application of planting technology. Many years of range revegetation and farming experience in the Northern Great Plains have identified planting procedures crucial for successful reestablishment of vegetation. Among these are the best methods for seeding and planting, the best methods and depths for covering different kinds of planted seeds, the best season to plant in each geographical locality, and the best kinds of mulch and methods of application to increase seed germination and seedling survival. Failure to apply all steps of the best planting procedures carefully can only result in reduced revegetation success.

6. *Fertilizers and soil amendments.*--As indicated earlier, the soils in Wyoming and Montana that characterize the western portion of the Northern Great Plains coal province are deficient in phosphorus. Similarly, the soils that characterize the eastern portion, mostly in North Dakota, exhibit nitrogen deficiencies. Despite these generalities, information is needed about the fertility regime of the surface several feet of mine spoils destined for revegetation. Fertilizers that supply nutrient deficiencies in these spoils must be applied for best revegetation success.

Spoil bank materials in the Northern Great Plains are nearly always alkaline. Most have a high saturation-percentage value, which stems from high clay content and cation composition. A high saturation-percentage value explains why many subsoils exposed by

strip mining are relatively high in salinity. This situation can often be corrected (e.g., by adding gypsum) provided sufficient planning and effort have identified saline surface spoils and the magnitude of salinity involved. Every effort should be made to bury spoils that have toxic saline levels.

7. *Irrigation*.--Erratic climatic conditions, especially in the amounts and distribution of precipitation, remain the dominant factor in success or failure of revegetation efforts on surface-mined sites carved from semiarid rangeland ecosystems. Accordingly, addition of irrigation water is sometimes desirable and even necessary to the establishment and survival of seedlings. Many subsurface and some surface water supplies have high sodium contents. Accordingly, newly planted mine spoils must be carefully and frequently irrigated, in association with the use of soil amendments, to avoid the development of unfavorable saline conditions.

8. *Spoil surface stabilization*.--As indicated, some spoil materials in the Northern Great Plains are fairly resistant to erosion by water and wind, whereas others are not. In general, the most highly erodible spoils, which usually contain more sodium on clays, occur in the North Dakota portion of the Northern Great Plains. This area also receives the most rainfall. Generally speaking, these two conditions combine to produce the heaviest overland flow and surface soil erosion on mine spoils. Under such conditions, it is desirable, probably necessary, to prevent or control surface instability if vegetation is to be established. Prevention or reduction of surface runoff and soil erosion from mine spoils can be achieved by a combination of measures, including grading to gentle slopes, terracing, pitting, and mulching. Failure to stabilize spoil surfaces against raindrop and runoff impacts prior to establishment of vegetation usually results in a high degree of rehabilitation failure.

9. *Post-rehabilitation care*.--Rehabilitation of such drastically disturbed sites as surface mine spoils is somewhat similar to planting and landscaping the yard of one's newly built home. It would be unthinkable to carefully plant a lawn, shrubs, trees, and flowerbeds and then to leave the plantings without further attention. It should be equally unthinkable to do everything necessary to insure successful rehabilitation of mine spoils, and then to forfeit the entire effort for lack of necessary subsequent care. In other words, the land must be managed during and after rehabilitation. When necessary, management involves measures to control destruction of new vegetation by insects, rodents, livestock, and big game. Measures may include fencing or the use of repellents to prevent or discourage damage from such sources.

10. *Rehabilitation time frames*.--The length of time required to successfully rehabilitate surface-mined sites depends upon essentially the same environmental factors that determine rehabilitation potentials. In other words, each kind of response unit probably has its own characteristic period required for successful rehabilitation under specified treatment. By assuming that response units of high potential rankings can be rehabilitated faster than those with low rankings and by considering the nature of revegetated plant cover on surface mines of relatively recent vintage, it is possible to speculate with some degree of reason about rehabilitation time frames. The author believes that the higher rated response units, which occur predominantly in North Dakota, can be rehabilitated successfully in from 1 to 5 years, depending upon whether the rehabilitation objective is agricultural cropland or mixed-grass range. On the medium-rated response units that dominate the moister areas of southeastern Montana and northeastern Wyoming, successful rehabilitation should be achieved in from 5 to 10 years, depending upon whether the rehabilitation objective is to return the land to short-grass prairie, a grass-shrub steppe, or a mixture of these types and ponderosa pine. On the lower-rated response units in the drier portions of northeastern Wyoming and northeastern Montana, from 5 to 15 years may be required to successfully return the land to the short-grass and/or shrub-steppe range that characterized it prior to mining.

During several consecutive years of above-normal precipitation, these time frames, particularly the longer ones, might be shortened substantially. On the other hand, during several consecutive years of drought, these time frames, especially the short ones, might be lengthened. No doubt, careful irrigation and fertilizing for the first several growing seasons would effectively shorten the time required to achieve successful rehabilitation.

11. *Rehabilitation objectives*.--In the Northern Great Plains, relatively few alternative rehabilitation objectives are feasible. Gentle topography, paucity of water, and lack of broad-scale variability in vegetation growth forms combine to limit feasible alternatives for rehabilitation objectives. The following objectives are not all inclusive, but they probably come close to delineating the feasible rehabilitation alternatives available in the Northern Great Plains:

a.--Return as nearly as possible to original range/forest condition;

b.--Return to previous agricultural cropland condition;

c.--Convert from previous range/forest condition to agricultural cropland;

d.--Convert from previous agricultural cropland to range/forest condition;

e.--Take advantage of such specialized features as water for ponds or lakes to develop unique recreation and/or wildlife habitat areas; and

f.--Develop such intensified land uses as airports, industrial or residential areas, solar energy sites, etc.

COSTS OF REHABILITATION

Revegetation costs include those of shaping spoils, use of topsoil or other suitable strata, seedbed preparation, seeding, fertilizing, soil amendments, mulching and, sometimes, irrigation. Largest expenses are usually those of shaping the land and surfacing with suitable material. Most estimates of rehabilitation costs emphasize either per-acre or per-ton costs. A more realistic alternative is to base costs on the stripping ratio (the cost as a function of area disturbed relative to the coal produced). Thus, economic considerations favor surface mining where coal seams are thick and overburden is thin. In the Northern Great Plains coal province, the lowest operating costs and the least area of disturbance per million tons of coal produced occur in Wyoming and Montana where thick coal seams are covered by relatively thin overburden. In contrast, the highest operating costs and the greatest unit disturbance per million tons of coal mined are found in North Dakota where coal seams are thinner and are more deeply buried. The thickest coal seams, the thinnest overburden, and the smallest acreage mined per million tons of coal production occur in those parts of the Northern Great Plains that have the lowest rehabilitation potentials.

Conversely, the greatest acreages of mine disturbance per million tons of coal occur in those parts of the Northern Great Plains that have the highest rehabilitation potentials. At the time of this writing (1974), estimates of direct on-site rehabilitation costs in these coalfields range from approximately $700 to $1,800 per acre, depending upon the location and the problems encountered. Rehabilitation costs include those of land shaping, seedbed preparation, seeding, fertilizing, soil amendments, water control on slopes, mulching, sediment control in detention basins, shrub or tree planting, and soil surfacing. Considering the tonnages of coal that will be mined per acre in the Northern Great Plains, mining operations apparently can bear the full expense of rehabilitation without adding more than a few cents per ton to the price of coal.

LEGAL BASIS FOR ENFORCEMENT OF SURFACE-MINE REHABILITATION

On the basis of information contained in this report, the author concludes that virtually all surface-mined lands in the Northern Great Plains can be successfully rehabilitated, albeit some more easily than others. However, this conclusion requires some qualification. Even on those rehabilitation-response units that have the highest rehabilitation potentials, rehabilitation will be successful only when (1) planning both in mining and rehabilitation is adequate and (2) monitoring and enforcement of rehabilitation is diligent over a meaningful period. Fulfillment of these qualifications depends upon effectual laws and administration, which, in turn, implies coordinated efforts by local, State, and Federal Government agencies. The Congress of the United States is actively considering legislation to regulate surface mining; however, to date, no Federal law has been adopted for the specific purpose of rehabilitating lands disturbed by mining. For the most part, neither Federal nor local regulations are explicit as to surface mining and rehabilitation. On the other hand, all States represented within the Northern Great Plains coal province have explicit laws in this regard. A summary was made of State legal requirements regarding the rehabilitation of surface-mined lands in the Northern Great Plains coal province. The information reveals that none of the States have complete legal authority covering all major rehabilitation requirements. Wyoming and Montana laws appear to be the most encompassing in this respect. North Dakota's law is somewhat less strict and South Dakota's law appears to be least stringent. In only 4 of 18 rehabilitation activities do *all* States have specifications. These specifications pertain to grading and shaping spoils, providing surface drainage, surfacing of spoils with topsoil, and revegetation. Differences in legal requirements for rehabilitation among just the four States involved here illustrate the need for improved coordination of the legal aspects of surface-mine rehabilitation.

INFORMATION AND RESEARCH NEEDS

Throughout this report, the need for more research and better information has been implied, evident, or stated. The most important of these informational and research needs are listed below:

1.--Analyze and evaluate chemical and physical characteristics of surface-mine overburden materials before mining in relation to their suitability for revegetation purposes;

2.--Test and evaluate various spoil segregations and configurations for enhancement of rehabilitation success;

3.--Develop methods and techniques for creating favorable microbiological activity in previously sterile surface-mine spoils;

4.--Test and evaluate the comparative effects of different organic soil amendments in the revegetation of surface-mine spoils;

5.--Test and evaluate comparative effects of selected inorganic fertilizers in the revegetation of surface-mine spoils;

6.--Evaluate the physical and chemical quality of surface and subsurface runoff water from mine spoils under different rehabilitation treatments;

7.--Develop mechanical-chemical-vegetative techniques for rehabilitating steep, abandoned surface-mine spoils;

8.--Evaluate the effectiveness of semiarid farming techniques known to be effective on various kinds of mine spoils;

9.--Determine limits of establishment techniques identified in 8 (above);

10.--Develop mechanical criteria for construction of mine dumps or massive spoils to prevent mass slumping and to reduce surface erosion;

11.--Determine the physiological tolerances of selected plant ecotypes to various soil-water potential stresses and atmospheric evaporative-demand stresses on surface-mine spoil sites;

12.--Determine physiological tolerances of selected plant ecotypes to saline-alkaline stresses on various kinds of surface-mine spoils;

13.--Test and evaluate hormone-stimulated rooting characteristics of native shrubs on abandoned, oversteep mine spoils;

14.--Apply tissue-culturing techniques to develop increased tolerances of selected plant ecotypes to saline-alkaline stresses on surface-mine spoils;

15.--Determine posttreatment management practices requisite to successful permanent revegetation.

ORGANIZATIONS PROMINENTLY ACTIVE IN NORTHERN GREAT PLAINS REHABILITATION WORK

The railroad companies strip-mined coal and rehabilitated some areas in North Dakota and Montana nearly a half century ago. However, most surface mining activity in the Northern Great Plains coal province has developed within the past 7 or 8 years, and nearly all rehabilitation efforts within the last 5 years. The most prominently active organizations involved in surface-mine rehabilitation work in the Northern Great Plains are industry, Federal agencies, and State institutions. The mining industry has provided most of the efforts so far. These efforts, however, have not always been successful, partially because of a lack of adequate technical direction. The Federal agencies most active in this regard have been the Agricultural Research Service, especially its laboratory at Mandan, North Dakota; the Forest Service's Intermountain and Rocky Mountain Forest and Range Experiment Stations; the Soil Conservation Service; and the Bureau of Land Management. Probably the most active State institutions have been the Agricultural Experiment Station at Montana State University and the University of Wyoming. Although the Montana Highway Department has not been working directly on rehabilitation of surface-mined lands, it has been active in rehabilitation work on highway cuts and fills. In some instances, this work has direct application to surface-mine rehabilitation problems.

CONCLUSIONS

This survey and analysis of rehabilitation experience and potentials of the major coal and bentonite surface mines in the Northern Great Plains indicate several rather common problems. Perhaps the most common is leaving steep spoil slopes on unstable soil associations. Rilling and gullying start quickly, particularly where spoils have high sodium contents. Such erosion washes seed and fertilizer from areas that need revegetation. It also deprives soil of moisture needed if plant cover is to become established and persist. Preferably, grading slopes to permit rehabilitation work should be done cross slope where possible. Overburden conditions that are adverse to plant growth are often overlooked, although they are probably recognized in many cases. The existence of spoils that support no vegetative cover after years of exposure bears out this contention. Such materials should be recognized and buried.

Solutions to many conditions that have been called problems can be achieved by common sense, together with interest in and knowledge about determinants of plant growth. Nevertheless, variability occurs in sites, even within a single rehabilitation-response unit, despite gross overall similarities that may exist in climate, soil, and vegetation. This variability in site microenvironment contains some of the constraints that negate hard and fast rules about rehabilitation potentials. Good rehabilitation will continue to require spot-by-spot application of sound principles of plant-soil-water relations.

The author believes that almost all surface-mined sites in the Northern Great Plains can be successfully rehabilitated. Sites having the highest rehabilitation potentials occur in response units characterized by productive and stable soils, suitable and available plant species, and adequate amounts of precipitation. In general, these high-potential sites are in west-central North Dakota. Surface mineable sites that have intermediate rehabilitation potentials are predominant in southeastern Montana and extreme western North Dakota. Sites having the poorest potentials for rehabilitation occur in northeastern Wyoming and northeastern Montana, where rehabilitation-response units are characterized by poorly productive soils, native species that grow slowly and are difficult to obtain for rehabilitation purposes, and low amounts of precipitation.

Fortunately, those portions of the Northern Great Plains that present the most difficult rehabilitation problems are also the smallest areas that will be disturbed for a given amount of extracted coal. Conversely, the easiest rehabilitation problems exist in those portions of the Northern Great Plains where the largest areas will be disturbed per unit of extracted coal.

Comparisons of the rehabilitation-potential rankings indicate lack of uniformity in the relative ease of the rehabilitation job along with a shift from one coal-development forecast to another and from one time frame to another. Even with differences in areas to be mined in each forecast and time frame accounted for, substantial increases and decreases in the average rehabilitation-potential rankings (table 13) exist; the difficulty of the rehabilitation job will vary substantially between development forecasts and time frames. The author concludes that restructuring of mining developments between time frames within each development forecast could be accomplished by reselecting for mining the combination of rehabilitation-response units that collectively are of almost the same rehabilitation-potential ratings from time frame to time frame. Uniformity of and, hence, standardization of rehabilitation activities and programs in the Northern Great Plains coalfields would be greatly improved.

Neither the Federal Government nor the States have totally adequate laws governing surface-mine rehabilitation in the Northern Great Plains. There is no Federal law, and State laws do not have uniformly adequate provisions to assure application of known technology for rehabilitation of surface-mined lands. Better laws and effective enforcement will be required before even the best rehabilitation technology can be applied effectively to the land.

The author believes that almost all the surface-mined lands of the Northern Great Plains can be rehabilitated successfully. However, a large amount of basic information needs to be collected, and numerous research problems require solutions before such rehabilitation can proceed expeditiously, effectively, and economically.

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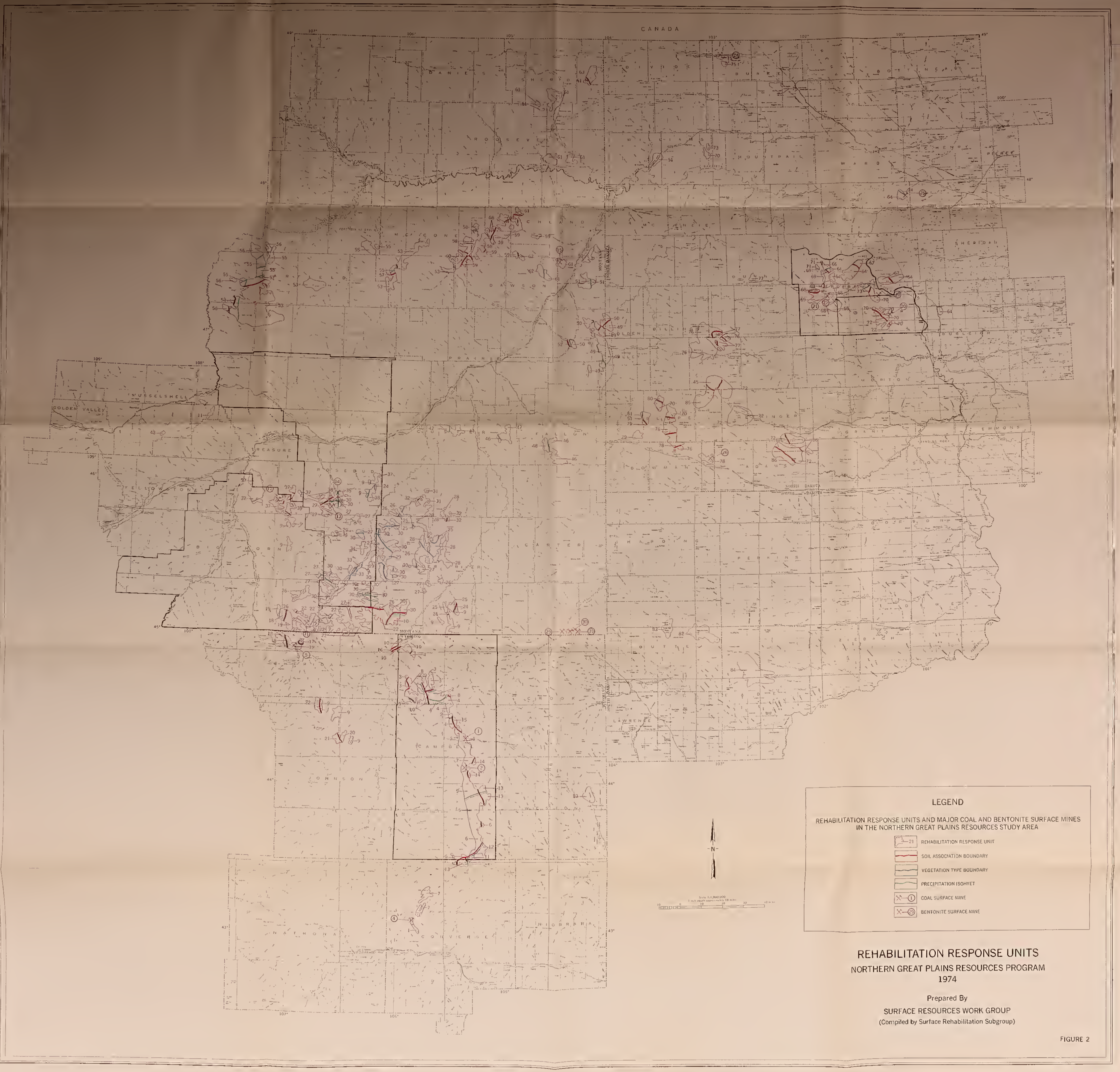

REHABILITATION RESPONSE UNITS

NORTHERN GREAT PLAINS RESOURCES PROGRAM

1974

Prepared By

SURFACE RESOURCES WORK GROUP

(Compiled by Surface Rehabilitation Subgroup)

FIGURE 2

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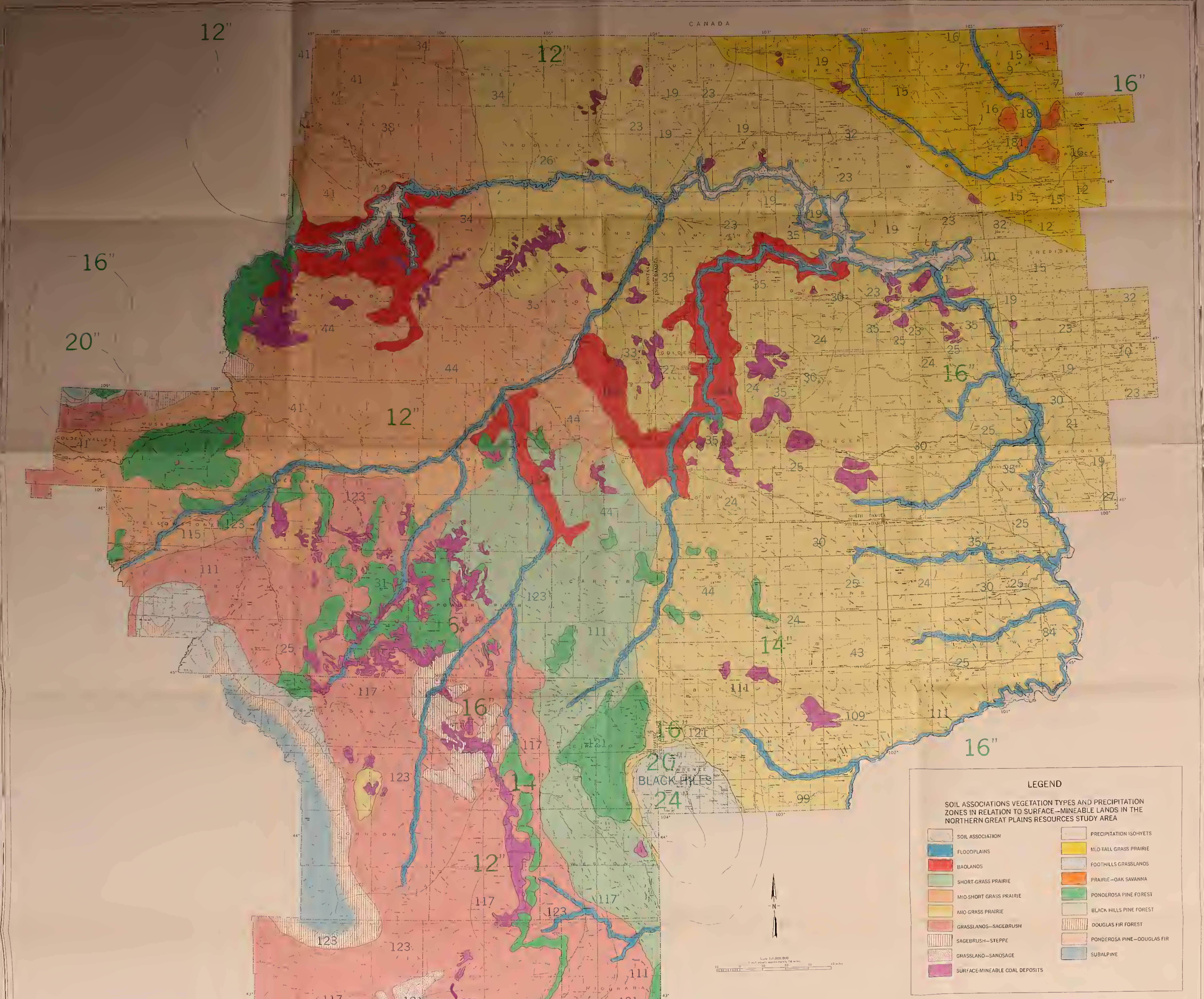

MAJOR ECO-SYSTEMS AND
SURFACE REHABILITATION FACTORS
NORTHERN GREAT PLAINS RESOURCES PROGRAM
1974

Prepared By
SURFACE RESOURCES WORK GROUP
(Compiled by Eco-Systems Subgroup and Surface Rehabilitation Subgroup)

FIGURE 1